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Proposed Re-evaluation Decision

Carbofuran

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Foreword

Proposed Re-evaluation Decision for Carbofuran

Health Canada's Pest Management Regulatory Agency (PMRA) has conducted the risk and value assessments for the insecticide carbofuran and its end-uses on food and feed crops. A summary of previous regulatory activity is provided below.

In June 1990, Agriculture and Agri-Food Canada announced a special review of carbofuran insecticide in response to concerns raised by the Canadian Wildlife Service of Environment Canada regarding the impact of this insecticide on vertebrate wildlife, especially birds. In July 1993, Agriculture and Agri-Food Canada published Discussion Document D93-02; *Special Review of Carbofuran Insecticide: Effects on Avian Fauna and Value to Agriculture*. The purpose of this document was to provide a summary of the data reviewed by Agriculture and Agri-Food Canada and Environment Canada on the risks and value of carbofuran, and to present possible regulatory options regarding the future registration status of carbofuran and each of its registered uses. The results of the discussion document were published in 1995 in the Decision Document E95-05, *Carbofuran*, which detailed the regulatory actions to be made as a result of the review of the data. Granular formulations as well as some uses of foliar applied carbofuran were discontinued to partly address avian risks.

In 2002, the PMRA announced the re-evaluation of carbofuran in a Re-evaluation Note REV2002-06, *Re-evaluation of Selected Carbamate Pesticides*.

An evaluation of available scientific information found that, under the current conditions of use, carbofuran products pose an unacceptable risk to human health and the environment and therefore do not meet Health Canada's current standards for human health and environmental protection. As a result, all uses of carbofuran are proposed for phase-out. This includes registered uses on canola, mustard, sunflower, corn (sweet, field and silage), sugar beet, green pepper, potato, raspberry and strawberry as well as temporary emergency uses on turnip and rutabaga. The emergency uses on turnip and rutabaga were registered for the period of April 1, 2008 to August 31, 2008 and are no longer registered for use in Canada, but were included at the time of assesssement.

The proposal affects all end-use products registered in Canada that contain carbofuran. This Proposed Re-evaluation Decision is a consultation document[1] that summarizes the science evaluation for carbofuran and presents the reasons for the proposed re-evaluation decision.

The PMRA will accept written comments on this proposal up to 60 days from the date of publication of this document. Please forward all comments to Publications.

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1 "Consultation statement" as required by subsection 28(2) of the *Pest Control Products Act*

Overview

Proposed Re-evaluation Decision for Carbofuran

After a re-evaluation of the insecticide carbofuran, Health Canada's Pest Management Regulatory Agency (PMRA), under the authority of the *Pest Control Products Act*, is proposing phase out of carbofuran products in Canada.

An evaluation of available scientific information found that, under the current conditions of use, carbofuran products pose an unacceptable risk to human health and the environment, and therefore do not meet Health Canada's current standards for human health and environmental protection. As a result, all uses of carbofuran are proposed for phase-out. This includes registered uses on canola, mustard, sunflower, corn (sweet, field and silage), sugar beet, green pepper, potato, raspberry and strawberry as well as temporary emergency uses on turnip and rutabaga. The emergency uses on turnip and rutabaga were registered for the period of April 1, 2008 to August 31, 2008 and are no longer registered for use in Canada, but were included at the time of this assessment.

The PMRA's pesticide re-evaluation program considers potential risks as well as the value of pesticide products to ensure they meet modern standards established to protect human health and the environment. Regulatory Directive DIR2001-03, *PMRA Re-evaluation Program*, presents the details of the re-evaluation activities and program structure. Re-evaluation draws on data from registrants, published scientific reports, information from other regulatory agencies, and any other relevant information available.

The proposal affects all end-use products registered in Canada that contain carbofuran. This Proposed Re-evaluation Decision is a consultation document that summarizes the science evaluation for carbofuran and presents the reasons for the proposed re-evaluation decision.

The information is presented in two parts. The Overview describes the regulatory process and key points of the evaluation, while the Science Evaluation provides detailed technical information on the human health, environmental and value assessment of carbofuran.

What Does Health Canada Consider When Making a Re-evaluation Decision?

The key objective of the *Pest Control Products Act* is to prevent unacceptable risks to people and the environment from the use of pest control products. Health or environmental risk is considered acceptable[2] if there is reasonable certainty that no harm to human health, future generations or the environment will result from use or exposure to the product under its conditions or proposed conditions of registration.The Act also requires that products have value[3] when used according to the label directions. Conditions of registration may include special precautionary measures on the product label to further reduce risk.

To reach its decisions, the PMRA applies hazard and risk assessment methods as well as policies that are rigorous and modern. These methods consider the unique characteristics of sensitive subpopulations in both humans (for example, children) and organisms in the environment (i.e. those most sensitive to environmental contaminants). These methods and policies also consider the nature of the effects observed and the uncertainties present when predicting the impact of pesticides. For more information on how the PMRA regulates pesticides, the assessment process and risk-reduction programs, please visit the Pesticides and Pest Management portion of Health Canada's website at http:/www.healthcanada.gc.ca/pmra.

Carbofuran is one of the carbamate pesticides re-evaluated as outlined in the Re-evaluation Note REV2002-06, *Re-evaluation of Selected Carbamate Pesticides*. The PMRA has considered all currently available information regarding health and environmental risk, including reviews from the United States Environmental Protection Agency (USEPA), as a source of information for conducting Canadian re-evaluation assessments.

Before making a final re-evaluation decision on carbofuran, the PMRA will consider all comments received from the public in response to this consultation document.[4] The PMRA will then publish a Re-evaluation Decision[5] on carbofuran, which will include the decision, the reasons for it, a summary of comments received on the proposed registration decision and the PMRA's response to these comments.

For more details on the information presented in this overview, please refer to the Science Evaluation section of this consultation document.

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2 "Acceptable risks" as defined by subsection 2(2) of the *Pest Control Products Act*

3 "Value" as defined by subsection 2(1) of the *Pest Control Products Act*: "the product's actual or potential contribution to pest management, taking into account its conditions or proposed conditions of registration, and includes the product's (a) efficacy; (b) effect on host organisms in connection with which it is intended to be used; and (c) health, safety and environmental benefits and social and economic impact".

4 "Consultation statement" as required by subsection 28(2) of the *Pest Control Products Act*

5 "Decision statement" as required by subsection 28(5) of the *Pest Control Products Act*

Regulatory Status in Organisation for Economic Cooperation and Development Countries

The USEPA reviewed the safety and benefits of all uses of carbofuran and concluded that ecological and human health risks were of concern.

On May 15, 2009, the USEPA issued a final rule[6] that it is revoking all of the existing carbofuran tolerences, referred to as maximum residue limits in Canada, on crops effective December 31, 2009, and will also move to cancel all remaining uses of carbofuran in the future.

What Is Carbofuran?

Carbofuran is a systemic, carbamate insecticide (Resistance Management Mode of Action group 1A), used to control a broad range of insect pests on certain field, vegetable and fruit crops. It is applied using conventional ground equipment to canola, mustard, sunflower, corn (sweet, field and silage), sugar beet, green pepper, potato, raspberry, strawberry, turnip and rutabaga and can also be applied by aerial equipment to corn (field, silage and sweet), canola and mustard. It may be applied by farmers, farm workers and professional applicators.

Health Considerations

Can Approved Uses of Carbofuran Affect Human Health?

Risks of concern to human health have been identified for both occupational and dietary carbofuran exposure.

Potential exposure to carbofuran may occur through diet (food and water) or when handling and applying the product. When assessing health risks, two key factors are considered: the levels where no health effects occur in animal testing and the levels to which people may be exposed. The dose levels used to assess risks are established to protect the most sensitive human population (for example, children and nursing mothers). Only uses for which the exposure is well below levels that cause no effects in animal testing are considered acceptable for registration.

Carbofuran was highly toxic via the oral route of exposure but was of low dermal toxicity in rats. Acute inhalation studies were not available. Carbofuran was a minimal eye irritant and was not a dermal sensitizer.

Acute overexposure to carbofuran can inhibit cholinesterase, an enzyme necessary for normal functioning of the nervous system. This can produce a variety of symptoms in animals and humans including: ataxia, salivation, lacrimation, tremors and breathing difficulties. With carbofuran, cholinesterase inhibition can occur rather rapidly with

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6 Federal Register (Volume 74, Number 93) Rules and Regulations

exposure (within minutes) but rapidly recovers along with the cessation of any of the aforementioned cholinergic symptoms. To prevent overexposure, label directions must be followed.

There was no evidence that carbofuran was carcinogenic or teratogenic. An assessment of mutagenic potential in a variety of in vitro and in vivo genotoxicity studies showed that carbofuran has weak mutagenic properties in bacterial and mammalian cells. A cancer risk assessment was not required. The nervous system was the main target of toxicity in rats, rabbits and dogs. At higher dose levels, the male reproductive system of rats, rabbits and dogs also appear to be targeted by carbofuran. When carbofuran was given to pregnant animals, effects on the developing fetus were observed at doses that were greater than those that were toxic to the mother, indicating that the fetus is not more sensitive to carbofuran than the adult animal.

Residues in Food and Water

Dietary risks from food are of concern.
Reference doses define levels to which an individual can be exposed over a single day (acute) or lifetime (chronic) and expect no adverse health effects. Generally, dietary exposure from food and water is acceptable if it is less than 100% of the acute reference dose or chronic reference dose (acceptable daily intake). An acceptable daily intake is an estimate of the level of daily exposure to a pesticide residue that, over a lifetime, is believed to have no significant harmful effects.

Acute dietary exposure to carbofuran as a percentage of the acute reference dose (ARfD) ranges from 311% for youth aged 13 to 19 years to 1501% for children aged 1 to 2 years, and is 579% for the general population. The acute dietary exposure to carbofuran is higher than the acute reference dose for all population subgroups; therefore, it is of concern.

Chronic dietary exposure to carbofuran as a percentage of the acceptable daily intake ranges from 10% for females aged 13 to 49 years to 35% for children aged 1 to 2 years old, and is 14% for the general population. The chronic dietary exposure to carbofuran is less than the acceptable daily intake for all population subgroups; therefore, it is not of concern.

An aggregate risk assessment combining exposure from food and drinking water was not conducted, as exposure from food alone is of concern.

The *Food and Drugs Act* prohibits the sale of food containing a pesticide residue that exceeds the established maximum residue limit (MRL). Pesticide MRLs are established for food purposes through the evaluation of scientific data under the *Pest Control Products Act.* Each MRL value defines the maximum concentration in parts per million (ppm) of a pesticide allowed in/on certain foods. MRLs for carbofuran are currently

established for carrots, onions, peppers, potatoes, rutabagas, turnips and strawberries. Where no specific MRL has been established, a default MRL of 0.1 ppm applies, which means that pesticide residues in a food commodity must not exceed 0.1 ppm. However, changes to this general MRL may be implemented in the future, as indicated in Discussion Document DIS2006-01, *Revocation of 0.1 ppm as a General Maximum Residue Limit for Food Pesticide Residues* [Regulation B.15.002(1)].

To protect the Canadian food supply and to mitigate dietary risks of concern, it is proposed that all MRLs for carbofuran be amended or revoked. Notwithstanding the general MRL of 0.1 ppm, the intent of this action to amend or revoke these MRLs is to prevent residues of carbofuran in or on foods. As noted above, changes to regulation B.15.002(1) may be implemented in future.

Risks in Residential and Other Non-Occupational Environments

Non-occupational risks are not of concern.
There are currently no residential uses of carbofuran. Given that homeowners would not be applying the product, a risk assessment for this scenario was not conducted.

Occupational Risks from Handling Carbofuran

Certain occupational mixer/loader/applicator risks are of concern.
Based on the precautions and directions for use on the product labels reviewed for this re-evaluation, risk estimates associated with certain mixing, loading and applying activities are of concern to the PMRA. All risk estimates for operators applying carbofuran by groundboom to turnips and rutabagas and by aircraft to corn did not reach the target margin of exposure (MOE) and/or aggregate risk index (ARI), even with maximum Personal Protective Equipment (PPE) and engineering controls, and are therefore of concern.

Certain occupational postapplication risks are of concern.
Postapplication occupational risk assessments consider exposures to workers entering treated sites in agriculture. Based on the precautions and directions for use on the existing carbofuran product labels for agricultural scenarios reviewed for this re-evaluation, postapplication risks to workers performing activities, such as thinning, pruning and harvesting of most crops, did not meet current standards and are of concern. The mitigation measures calculated to reduce post-application risk may be agronomically unfeasible.

Environmental Considerations

What Happens When Carbofuran Is Introduced into the Environment?

Carbofuran poses a potential risk to terrestrial and aquatic organisms.

When carbofuran is released into the environment some of it can be found in soil and surface water. Carbofuran is highly mobile in soils and can therefore leach into groundwater and enter surface water in runoff. Carbofuran breaks down into several transformation products through hydrolysis, phototransformation and moderate biotransformation at rates that depend on environmental conditions. Hydrolysis is faster in water with a pH > 6 (basic conditions), with a half-life ranging from a few hours to 28 days. Carbofuran is stable to hydrolysis in acidic water (pH < 7). Phototransformation is fast in water, with a half-life of 6 days. Carbofuran is persistent in acidic soils (half life of 321 days) and moderately persistent in soils with a pH > 7 (half-life 149 days). Carbofuran is not expected to volatilize significantly and has a low potential for bioaccumulation in biota.

Carbofuran poses a risk to both terrestrial and aquatic organisms. Birds and small wild mammals are at risk in and around the site of application due to the consumption of contaminated food items, and the risk cannot be mitigated.

Thirty three environmental incident reports, from the United States and Canada were considered during the review of carbofuran, and indicated that exposure to carbofuran under the currently registered use pattern resulted in avian, small wild mammal and bee mortality.

Value Considerations

What Is the Value of Carbofuran?

For the control of some pests in agriculture, carbofuran is the only insecticide available, or there are few viable registered alternative products to carbofuran.

Carbofuran is absorbed by the host plant, providing a systemic mode of action in addition to contact action. It is effective in two ways:

- as a contact insecticide, killing target insects upon direct contact and;
- as an insecticide that works as a stomach poison, killing target insects upon ingestion of treated plants.

Being a systemic insecticide, carbofuran is absorbed and transported throughout the plant, imparting protection to the entire plant. Systemic insecticides are effective against insects with piercing-sucking mouthparts, such as leafhoppers, spittlebugs and tarnished plant bug, as the systemic insecticide moves within the vascular tissues and into plant cells where these pests feed.

As a systemic insecticide which acts upon ingestion, carbofuran is effective for the control of pests that otherwise could not be targeted by contact insecticides, or non-systemic insecticides that act as a stomach poison, such as chewing insects, once they enter the host plants. For example, European corn borer larvae bore into the midrib of the leaf and migrate into the stalk of the plant or husk of the ear (corn), or feed inside the stems and fruit (pepper).

For canola, mustard, raspberry, strawberry and sugar beet, as well as turnip and rutabaga (temporary uses) there are no registered (or viable) alternative active ingredients to carbofuran for the control of certain pests.

Measures to Minimize Risk

All products containing carbofuran are proposed for phase out since, based on available scientific information, they do not meet Health Canada's current standards for human health and environmental protection and pose unacceptable risks to human health and the environment. Additional mitigation measures are not being proposed at this time.

What Additional Scientific Information Is Requested?

The PMRA is seeking quantitative and/or qualitative information on the economic and social importance of carbofuran to specific industries and information on the availability and viability of alternative chemical and non-chemical pest management practices for the site and pest combinations registered for carbofuran. This information will allow the PMRA to refine sustainable pest management options for uses of carbofuran.

Next Steps

Before making a re-evaluation decision on carbofuran, Health Canada's Pest Management Regulatory Agency will consider all comments received from the public in response to this consultation document. The PMRA will also consider quantitative and/or qualitative information on the economic and social importance of carbofuran to specific industries and information on the availability and viability of alternative chemical and non-chemical pest management practices for the site and pest combinations registered for carbofuran.

Health Canada's Pest Management Regulatory Agency will then publish a Re-evaluation Decision, which will include the decision, the reasons for it, a summary of comments received on the proposed decision and the PMRA's response to these comments.

Once all carbamate pesticides have been re-evaluated, a cumulative risk assessment will be conducted, which will consider potential exposure to all chemicals with the same mechanism of toxicity. The results of the cumulative risk assessment may affect any previous re-evaluation decisions.

Other Information

At the time that the re-evaluation decision is made, the PMRA will publish an Evaluation Report on carbofuran in the context of this re-evaluation decision (based on the Science Evaluation section of this consultation document). In addition, the test data on which the decision is based will also be available for public inspection, upon application, in the PMRA's Reading Room (located in Ottawa, Ontario, Canada).

Science Evaluation

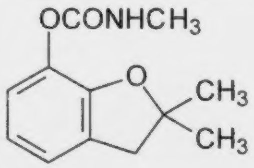
1.0 Introduction

Carbofuran is a broad spectrum systemic carbamate insecticide belonging to the resistance management Mode of Action (MoA) group 1A, and is an acetylcholinesterase inhibitor. It works by contact and stomach action.

Following the re-evaluation announcement for carbofuran, FMC Corporation, the registrant of the technical grade active ingredient (TGAI) and primary data provider in Canada, indicated that it intended to provide continued support for all uses included on the label of Restricted Class end-use products.

2.0 The Technical Grade Active Ingredient, Its Properties and Uses

2.1 Identity of the Technical Grade Active Ingredient

Common name			Carbofuran
Function			Insecticide, nematicide
Chemical Family			Carbamate
Chemical name			
	1	**International Union of Pure and Applied Chemistry (IUPAC)**	2,3-dihydro-2,2-dimethylbenzofuran-7-yl methylcarbamate
	2	**Chemical Abstracts Service (CAS)**	2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate
CAS Registry Number			1563-66-2
Molecular Formula			$C_{12}H_{15}NO_3$
Structural Formula			
Molecular Weight			221.3

Purity of the Technical Grade Active Ingredient	95% MU
Registration Number	19169

Identity of relevant impurities of human health or environmental concern:

Due to the presence of a secondary amine functional group in carbofuran and several of its impurities, these chemicals could be precursors of the corresponding nitrosamine derivatives. Based on the proposed decision, the potential for nitrosamines will not be further investigated at this time.

2.2 Physical and Chemical Properties of the Technical Active Ingredient

Property	Result
Vapour pressure	0.031 mPa at 20°C 0.072 mPa at 20°C
Ultraviolet (UV)/visible spectrum	Not expected to absorb at λ >300 nm
Solubility in water	320 mg/L at 20°C 351 mg/L at 25°C
n-Octanol/water partition coefficient (Log K_{ow}) at 20°C	Log K_{ow} = 1.52
Dissociation constant	None

2.3 Description of Registered Carbofuran Uses

Appendix I lists all carbofuran products that are registered under the authority of the Pest Control Products Act. Appendix II lists all the uses for which carbofuran is presently registered. All uses were supported by the registrant at the time of re-evaluation initiation and were therefore considered in the health and environmental risk assessments of carbofuran. Also presented is information on whether the use was added through the PMRA Minor Use Program.

Uses of carbofuran belong to the following use-site categories: industrial oilseed and fibre crops, terrestrial feed crops and terrestrial food crops.

3.0 Impact on Human Health and Animal Health

3.1 Toxicological Summary

A detailed review of the toxicological database for carbofuran was conducted. The toxicology database for carbofuran is primarily based on studies from the registrant. Numerous studies from *Industrial Bio-Test Laboratory* with carbofuran were available but few were found to be validated; invalidated studies or studies with no validation reports were not used for re-evaluation.

Carbofuran was rapidly absorbed, metabolized and eliminated mainly in the urine after oral administration to mice and rats. The first step in the metabolic pathway is hydroxylation of carbofuran to 3-hydroxycarbofuran then oxidation resulting in the formation of 3-ketocarbofuran. Breakage of the carbamate ester linkage results in liberation of the phenolic derivatives and their corresponding conjugates, principally glycosides. These degradation products are then excreted mainly as conjugates of glucuronic acid and sulfate. The most common carbamate metabolites are 3-hydroxycarbofuran and 3-ketocarbofuran. There were no sex differences noted in the absorption, distribution, metabolism or excretion of carbofuran. Most metabolites were found to be significantly less toxic than the parent compound in acute oral lethality tests. One metabolite 3-hydroxycarbofuran showed similar acute oral toxicity as carbofuran.

In acute toxicity studies, carbofuran was highly toxic via the oral route of exposure in rats but showed low dermal toxicity. Acute inhalation studies were not available. Carbofuran was a minimal eye irritant and was not a dermal sensitizer. The acute effects observed in oral studies were typical for cholinesterase inhibition: ataxia, salivation, lacrimation, exophthalmos, hyperpnea, cyanosis and generalized tremors. As with other carbamate compounds, carbofuran's cholinesterase-inhibiting effect is short-term and reversible.

In repeat-dose dietary studies in various species (mouse, rat and dog), the dog appeared to be the most sensitive species with respect to cholinergic symptoms. Cholinesterase inhibition was seen in all species with the mouse being the least sensitive. Inhibition of cholinesterase activity is also seen via the dermal route of entry in the rabbit. Repeat-dose inhalation studies were not available. No gender sensitivities were seen in repeat-dose dietary studies. Additional effects noted in the repeat-dose dietary studies include: a decrease in weight gain in mice and rats and testicular effects in dogs. The rodent studies highlight the differences between gavage and dietary dosing as animals tolerated chronic dietary dose-levels that were equivalent to or even exceeded the LD_{50}s in acute gavage studies. Repeat-dose dietary studies in the rat and dog did not indicate that an increase in the duration of dosing resulted in increased toxicity with respect to cholinesterase activity and/or effects.

Although no guideline acute neurotoxicity study was available, two published studies provided consistent results. In Cambon et al. (1979), single gavage doses of 0.05 mg/kg bw or greater to pregnant rats on gestation day 18 resulted in reduced cholinesterase activity with peak effects at 1 hour post-dosing. In a metabolism study by Ferguson et al. (1984), a gavage dose of 0.05 mg/kg bw also inhibited erythrocyte cholinesterase at 15 minutes post-dosing with recovery by 3 hours. These studies highlight the short-acting effects typically associated with carbamate inhibitors of cholinesterase.

Subchronic neurotoxicity studies (dietary) showed clinical signs, decreased motor activity and altered neurological functioning but lacked cholinesterease measurements. Results from the chronic rat study suggest that cholinesterase inhibition was occurring at the levels causing the neurological impairment. In a developmental neurotoxicity study (dietary), doses high enough to cause neonatal death, marked growth retardation and developmental delays did not cause persistent neurological effects. No evidence of neuropathology was noted in any of the available studies.

Assessments of mutagenic potential in a variety of bacterial and mammalian *in vitro* and *in vivo* studies were performed for carbofuran. Positive results in studies with bacteria have been recorded in *S. typhimurium* (TA 1535 and occasionally TA 98 & TA 1538), while negative results have been reported in other strains of *S. typhimurium, S. cerevisiae, E. coli and B. subtillis.* In the mouse lymphoma mutagenesis assay, carbofuran displayed weak positive results. Positive evidence from other tests includes the *in vivo* chromosomal aberration assay and micronucleus assay; however, these positive results occurred at levels noted to induce lethality in the acute LD_{50} studies. Negative results were achieved with the Drosophila sex-linked recessive lethal mutation, mitotic recombination in yeast, *in vitro* chromosome aberration, sister chromatid exchange and unscheduled DNA synthesis assays. There is sufficient evidence to support weak mutagenic properties for carbofuran in bacteria and mammalian cells.

Studies for chronic toxicity/carcinogenicity were conducted on mice and rats. In all studies reviewed, there was no evidence of carcinogenicity.

The developmental toxicity studies in mice, rats and rabbits showed no evidence of teratogenicity and no additional sensitivity of the fetus following *in utero* exposure to carbofuran. Developmental effects in the fetuses included mortality, decreased weight and increased variations alongside maternal observations of mortality, clinical signs and reduced weight gain.

At higher dose levels, carbofuran caused sperm and reproductive system damage when fed to either adult male rats or rats exposed *in utero* or during lactation (Pant et al., 1995, 1997). Degeneration was seen in the Sertoli cells along with atrophied seminiferous tubules. Disturbed spermatogenesis (decreased sperm count, abnormal sperm morphology and altered testicular enzymes) was noted in the rats. Yousef et al. (1995) also found effects on sperm quantity and quality in carbofuran-treated rabbits. In the one-year dog study, testicular effects were manifested as decreased weight, degeneration of the seminiferous tubules and aspermia. Despite these effects, no reproductive effects were noted in the multigeneration reproductive study. Parental

effects were limited to reduced weight gain and food intake whereas offspring effects included reduced weight gain and viability. In view of the findings in the rat, rabbit and dog, carbofuran should be viewed as having some potential for reproductive toxicity.

Reference doses have been established based on NOAELs for the most relevant endpoints, namely the cholinesterase inhibiting property of carbofuran. These reference doses incorporate various uncertainty factors to account for extrapolating between laboratory animals and humans and for variability within the human populations as well as relevant *Pest Control Products Act* (PCPA) factors.

Results of the acute and chronic tests conducted on laboratory animals with carbofuran technical, along with the toxicology endpoints for use in the human health risk assessment, are summarized in Tables 1 and 2 of Appendix III.

3.1.1 PCPA Hazard Consideration

For assessing risks from potential residues in food or from products used in or around homes or schools, the *Pest Control Products Act* (PCPA) requires the application of an additional 10-fold factor to threshold effects. This factor should take into account completeness of the data with respect to the exposure of, and toxicity to, infants and children and potential pre- and post-natal toxicity. A different factor may be determined to be appropriate on the basis of reliable scientific data.

With respect to the completeness of the toxicity database as it pertains to the exposure of and toxicity to infants and children, numerous studies were available for carbofuran, including three developmental toxicity studies in rats, two developmental toxicity studies in rabbits and a multigeneration reproduction study in rats. As well, acute and short-term neurotoxicity studies, a developmental neurotoxicity study along with some supplemental studies were available. Since the main target of toxicity for carbofuran in all of the species evaluated was the nervous system, the reference doses were selected based on the clinical signs of neurotoxicity and cholinesterase inhibition noted throughout the database. Regulating on the most sensitive indicator of toxicity was considered protective of any other toxicological effects that could be attributed to carbofuran exposure. Based on the available studies, it was not deemed necessary to retain the PCPA factor; however, a well-conducted comparative cholinesterase study would enable a more thorough examination of the potential for sensitivity of the young.

With respect to potential pre-and post-natal toxicity, developmental toxicity studies in rats and rabbits provided no indication of increased susceptibility of fetuses to *in utero* exposure. There was no indication of increased susceptibility in the offspring compared to parental animals in the three-generation rat reproduction study. Based on the results of these studies, there is a low level of concern for potential pre- and post-natal toxicity associated with carbofuran.

3.2 Occupational and Non-Occupational Risk Assessment

Occupational and non-occupational risk is estimated by comparing potential exposures with the most relevant endpoint from toxicology studies to calculate a margin of exposure (MOE). This is compared to a target MOE incorporating uncertainty factors protective of the most sensitive subpopulation. If the calculated MOE is less than the target MOE, it does not necessarily mean that exposure will result in adverse effects. However, MOEs less than the target MOE require measures to mitigate (reduce) risk. For some scenarios, combined MOEs could not be calculated for combined dermal, inhalation and incidental oral exposures since each route of exposure had different NOAELs and target MOEs. Therefore, an aggregate risk index (ARI) was calculated. ARIs greater than or equal to 1 do not require risk mitigation.

3.2.1 Toxicology Endpoint Selection for Occupational Risk Assessment

3.2.1.1 Short- and Intermediate-Term Dermal Risk Assessment

For occupational short-term and intermediate-term dermal risk assessment (1 to 30 days and 1 month to several months, respectively), the dermal NOAEL of 10 mg/kg bw/day from the 21-day dermal toxicity study in rabbits was selected. The target Margin of Exposure (MOE) selected when using this study is 100 thus accounting for standard uncertainty factors of 10-fold for interspecies extrapolation and 10-fold for intraspecies variability.

3.2.1.2 Short- and Intermediate-Term Inhalation Risk Assessment

Since there are no repeat-dose inhalation studies available for inhalation risk exposure, it is appropriate to assume that absorption via inhalation exposure is equivalent to oral absorption.

For a short- and intermediate- term exposure (up to several months), the acute oral cholinesterase activity studies in the rat were chosen with a LOAEL of 0.05 mg/kg bw based on inhibition of cholinesterase. The target MOE selected when using these studies is 300; this accounts for standard uncertainty factors of 10-fold for interspecies extrapolation, 10-fold for intraspecies variability and an additional 3-fold uncertainty factor because a NOAEL was not achieved in this study.

3.2.1.3 Dermal Absorption

A dermal absorption factor is not applicable for the dermal risk assessment since the toxicological endpoint for dermal exposure was based on a dermal study.

3.2.2 Occupational Exposure and Risk Assessment

Workers can be exposed to carbofuran through mixing, loading or applying the pesticide, and when entering a treated site to conduct activities such as scouting and/or handling of treated crops and/or harvesting.

3.2.2.1 Mixer, Loader and Applicator Exposure and Risk Assessment

There are potential exposures to mixers, loaders, and applicators. The following uses were assessed:

- Applying liquids by air or by groundboom to canola, mustard and corn (field, silage and sweet);
- Applying liquids by groundboom to sunflowers, green peppers, potatoes, sugar beets, strawberries and raspberries, as well as to rutabagas and turnips (temporary uses).

Due to the number of agricultural applications per year (ranging from 1 to 3), exposure is likely to be short- to intermediate-term (i.e. up to several months) in duration. The PMRA estimated handler exposure based on different levels of personal protection:

A. Mixing and loading liquids:
An open mixing and loading system with maximum personal protection equipment (PPE). Maximum PPE: Chemical resistant coveralls over a single layer (long-sleeved shirt and long pants) with chemical resistant gloves and a suitable respirator.

B. Applying by air:
A single layer (long sleeved shirt and long pants), no gloves.

C. Applying by groundboom:
A closed cab with maximum personal protection equipment (PPE).
Maximum PPE: Chemical resistant coveralls over a single layer (long sleeved shirt and long pants).

No acceptable chemical-specific handler exposure data were submitted for carbofuran; therefore, dermal and inhalation exposures were estimated using data from the Pesticide Handlers Exposure Database (PHED), Version 1.1. The PHED is a compilation of generic mixer/loader and applicator passive dosimetry data with associated software that facilitates the generation of scenario-specific exposure estimates based on formulation type, application equipment, mix/load systems and level of PPE.

In most cases, PHED did not contain appropriate data sets to estimate exposure to workers wearing chemical-resistant coveralls or a respirator. This was estimated by incorporating a 90% clothing protection factor for chemical resistant coveralls.

In addition, a 90% protection factor for a respirator was incorporated into the inhalation unit exposure data. Respirators were not considered in conjunction with closed systems.

Inhalation exposures were based on light inhalation rates (17 Litres per minute (LPM)).

Occupational risk estimates associated with applying, mixing and loading for certain agricultural uses do not meet the targets, even when engineering controls and/or PPE are used as summarized in Section 7. Table 1 of Appendix IV summarizes the calculated MOEs for mixers/loaders and applicators.

Mixer/loader/applicator exposure estimates are based on the best available data at this time.

3.2.2.2 Postapplication Worker Exposure and Risk Assessment

The postapplication occupational risk assessment considered exposures to workers entering treated agricultural sites. Based on the carbofuran use pattern, there is potential for short-to intermediate-term postapplication exposure to carbofuran residues for workers. Postapplication exposure activities include (but are not limited to): hand harvesting, pinching, pruning, and thinning agricultural crops.

No chemical-specific dislodgeable foliar residue (DFR) data were submitted to the PMRA for consideration. As there were no DFR studies submitted to the PMRA, the default peak (day 0) DFR value of 20% of the application rate and the default dissipation rate of 10% per day were used in the assessment. Activity specific transfer coefficients (TC) were used to estimate postapplication exposure resulting from contact with treated foliage at various times after application. DFR data include the amount of residue that can be dislodged or transferred from a surface, such as the leaves of a plant. A TC is a factor that relates worker exposure to dislodgeable residues. TCs are specific to a given crop and activity combination (e.g. hand harvesting green peppers, scouting late season corn) and reflect standard work clothing worn by adult workers.

For workers entering a treated site, restricted entry intervals (REIs) are calculated to determine the minimum length of time required before people can safely enter. An REI is the duration of time that must elapse before residues decline to a level where performance of a specific activity results in exposures above the target MOE (i.e. > 100 for short- to intermediate-term exposure scenarios).

For agricultural scenarios, based on available data, to achieve the target MOEs for postapplication workers, most current REIs would need to be increased in length. Table 2 of Appendix IV summarizes calculated REIs for selected agricultural postapplication activities, based on currently available exposure data, and the target MOE of 100.

Based on the risk assessment, the postapplication risks to workers performing high-exposure activities, such as hand harvesting treated turnips, rutabaga and seed corn, do not meet the target MOE (i.e. MOE > 100), until 32 days after treatment. These REIs may not be considered agronomically feasible for growers.

3.2.3 Non-Occupational and Residential Exposure and Risk Assessment

Non-occupational risk assessment is concerned with estimating risks to the general population, including children, during or after pesticide application in and around the home. Given that there are no domestic products for carbofuran nor are there any residential uses, a non-occupational assessment was not conducted.

3.3 Dietary Risk Assessment

In a dietary exposure assessment, the PMRA determines how much of a pesticide residue, including residues in milk and meat, may be ingested with the daily diet. Exposure to carbofuran from potentially treated imports is also included in the assessment. These dietary assessments are age specific and incorporate the different eating habits of the population at various stages of life. For example, the assessments take into account differences in children's eating patterns, such as food preferences and the greater consumption of food relative to their body weight when compared to adults. Dietary risk is then determined by the combination of the exposure and the toxicity assessments. High toxicity may not indicate high risk if the exposure is low. Similarly, there may be risk from a pesticide with low toxicity if the exposure is high.

The PMRA considers limiting use of a pesticide when risk exceeds 100% of the reference dose. Health Canada's Science Policy Note SPN2003-03, *Assessing Exposure from Pesticides, A User's Guide*, presents detailed acute and chronic risk assessments procedures.

Acute and chronic dietary exposure and risk assessments were conducted for carbofuran using the Dietary Exposure Evaluation Model - Food Commodity Intake Database™ (DEEM-FCID™, Version 2.03), which incorporates consumption data from the United States Department of Agriculture's Continuing Surveys of Food Intakes by Individuals (CSFII), 1994-1996 and 1998.

For more information on dietary risk estimates or residue chemistry information used in the dietary risk assessment, see Appendices V to VIII.

3.3.1 Determination of Acute Reference Dose

To estimate acute dietary risk (1 day), the LOAEL of 0.05 mg/kg body weight was selected from the two acute oral cholinesterase activity studies in the rat based on cholinesterase inhibition (Cambon et al., 1979 and Ferguson, et al., 1984). Standard uncertainty factors of 10-fold for interspecies extrapolation and 10-fold for intraspecies variability were applied along with an additional 3-fold uncertainty factor because a NOAEL was not achieved in these studies. With respect to the PCPA factor, all of the required studies relevant to assessing risks to infants and children were available for this assessment. Accordingly, the PCPA factor was reduced to 1-fold and the composite assessment factor was 300.

$$\textbf{ARD} = \frac{\textbf{0.05 mg/kg bw/day}}{\textbf{300}} = \textbf{0.0002 mg/kg bw}$$

3.3.2 Acute Dietary Exposure and Risk Assessment

Acute dietary risk is calculated considering the highest ingestion of carbofuran that would be likely on any one day, and using food consumption and food residue values. A statistical analysis allows all possible combinations of consumption and residue levels to be combined to estimate a distribution of the amount of carbofuran residue that may be consumed in a day. A value representing the high end (99.9^{th} percentile) of this distribution is compared to the acute reference dose, which is the dose at which an individual could be exposed on any given day and expect no adverse health effects. When the expected intake of residues is less than the acute reference dose, the expected intake is not considered to be a health concern.

The acute dietary exposure was calculated using a refined probabilistic assessment. Refinements for commodities on which use of carbofuran is registered in Canada or other countries include generating residue distribution files that incorporated the following, where appropriate:

- surveillance data from the CFIA and the United States,
- empirical data from magnitude of residue (MOR) studies,
- processing studies,
- estimates of the percentage of a commodity that is treated,
- estimates of Canadian production of food commodities or percentages imported from other countries.

The acute dietary assessment was conducted based on current uses of carbofuran in Canada, including the temporary emergency uses on turnip and rutabaga that are no longer registered. Acute risk was estimated with and without these uses.

When including the turnip and rutabaga uses, acute dietary exposure to carbofuran as a percentage of the acute reference dose (ARfD) ranges from 311% for youth aged 13 to19 years to 1501% for children aged 1 to 2 years, and is 579% for the general population. The acute dietary exposure to carbofuran is higher than the ARfD for all population subgroups; therefore, it is of concern.

Without the turnip and rutabaga uses, acute dietary exposure to carbofuran as a percentage of the ARfD ranges from 108% for adults aged 50+ years to 360% for children aged 1 to 2 years, and is 180% for the general population. The acute dietary exposure to carbofuran is higher than the ARfD for all population subgroups; therefore, it is of concern.

3.3.3 Determination of Acceptable Daily Intake

To estimate dietary risk from repeat exposure, the two acute oral cholinesterase activity studies in the rat (as discussed under 3.3.1 Determination of Acute Reference Dose) were selected for risk assessment. The quick-acting and reversible nature of carbamate inhibition is considered as justification to default to the acute LOAEL which is lower than the subchronic or chronic NOAELs. In the case of carbofuran, long-term daily exposures are considered as multiple daily

exposures with each causing transient inhibition of cholinesterase with potential resulting toxicity. Standard uncertainty factors of 10-fold for interspecies extrapolation and 10-fold for intraspecies variability were applied along with an additional 3-fold uncertainty factor because a NOAEL was not achieved in these studies. With respect to the PCPA factor, all of the required studies relevant to assessing risks to infants and children were available for this assessment. Accordingly, the PCPA factor was reduced to 1-fold and the composite assessment factor was 300.

$$\textbf{ADI} = \frac{\textbf{0.05 mg/kg bw/day}}{\textbf{300}} = \textbf{0.0002 mg/kg bw/day}$$

This ADI provides a margin of safety of >2,500 to the developmental NOAEL (decreased viability) >500 to the lowest NOAEL for testicular effects and >1,000 to the lowest LOAEL for maternal toxicity. It is thus considered protective of all populations including men, pregnant women, infants and children.

3.3.4 Chronic Dietary Exposure and Risk Assessment

Chronic dietary exposure is calculated using the average consumption of different foods and average residue values on those foods. This expected intake of residues is compared to the acceptable daily intake, which is the dose at which an individual could be exposed over the course of a lifetime and expect no adverse health effects. When the expected intake from residues is less than the acceptable daily intake, this intake is not considered to be of concern. The chronic dietary exposure was calculated using a refined deterministic assessment. As with the acute assessment, refinement for the chronic assessment included use of the following, where appropriate:

- Surveillance data from the Canadian Food Inspection Agency and the United States
- Empirical data from magnitude of residue (MOR) studies,
- Processing studies,
- Estimates of the percentage of a commodity that is treated,
- estimates of Canadian production of food commodities or percentages imported from other countries.

Chronic dietary exposure to carbofuran as a percentage of the Acceptable Daily Intake (ADI) ranges from 10% for females aged 13 to 49 years to 35% for children aged 1 to 2 years, and is 14% for the general population. The chronic dietary exposure to carbofuran is less than the ADI for all Canadians; therefore, it is not of concern.

3.4 Exposure from Drinking Water

Since acute exposure exceeds the ARfD for food alone, any additional exposure through drinking water would be of concern.

3.5 Aggregate Risk Assessment

Aggregate exposure is the total exposure to a single pesticide that may occur from food, drinking water, residential and other non-occupational sources as well as from all known or plausible exposure routes (oral, dermal and inhalation).

Aggregate risk assessment looks at the combined potential risk associated with food, drinking water and residential exposures. Given that carbofuran does not have any residential uses, the aggregate risk assessment therefore, is from dietary and drinking water exposures only. The combined exposures from diet and drinking water are compared to the ARfD for the acute assessment (one-day exposure) and the ADI for the chronic assessment.

An aggregate risk assessment for carbofuran was not conducted since the acute dietary risk from food alone is of concern.

3.6 Incident Reports Related to Human Health

Starting April 26, 2007, registrants are required by law to report incidents, including adverse effects to health and the environment, to the PMRA within a set time frame. Specific information regarding the mandatory reporting system regulations can be found at www.hc-sc.gc.ca/cps-spc/pest/registrant-titulaire/reporting-declaration/mandatory-obligatoire/index-eng.php

Incidents are classified into six major categories including effects on humans, effects on domestic animals and packaging failure. Incidents are further classified by severity, in the case of humans for instance, from minor effects such as skin rash, headache, etc., to major effects such as reproductive or developmental effects, life-threatening conditions or death.

The PMRA will examine incident reports and, where there are reasonable grounds to suggest that the health and environmental risks of the pesticide are no longer acceptable, appropriate measures will be taken, ranging from minor label changes to discontinuation of the product.

There was one incident report related to human health that was submitted to the PMRA for carbofuran. The report indicates that the protective clothing required by carbofuran labels for the use was not worn during spraying. The individual was treated and released from hospital. No other incidents involving human health have been reported to the PMRA as of 29 September 2008.

In the United States, the USEPA states that more than 700 possible carbofuran poisoning incidents were reported (USEPA, 2007). In most cases, symptoms for carbofuran incidents were specific to cholinergic poisoning and most resulted from dermal and inhalation exposure, rather than oral exposure, and the majority of illnesses were of a systemic type. Eye problems were also widely reported, accounting for approximately one quarter of all recorded incidents. Causes of these incidents included: failure to wear appropriate personal protective equipment, exposure during cleaning or repair of spray equipment, spray drift or early entry into treated fields. The

majority of incidents occurred among handlers who mix, load, and apply carbofuran in agricultural fields. The USEPA concluded that the number and rate of poisoning cases due to carbofuran exposure is sufficient to warrant priority attention to risk reduction measures for this pesticide.

For a review of the pesticide poisoning incident data for carbofuran, the USEPA consulted the following databases: (1) OPP Incident Data System (IDS); (2) Poison Control Centres (PCC); (3) California Department of Pesticide Regulation; (4) National Pesticide Telecommunications Network (NPTN), and (5) National Institute of Occupational Safety and Health's Sentinel Even Notification System for Occupational Risks (NIOSH SENSOR).

3.7 Data Gaps Related to Health Risk Assessment

The following data gaps were identified during the re-evaluation, however they will not be formally pursued with the registrant in light of the proposed phase out.

- Acute inhalation study
- Dermal irritation study
- Comparative cholinesterase inhibition study (dams versus pups)
- A short-term inhalation study.
- Livestock Metabolism/Residue Definition in Livestock Matrices
- Plants Metabolism/Residue Definition in Plants Matrices
- Supervised Residue Trial Analytical Methodology
- Enforcement Analytical Methodology
- Inter-Laboratory Analytical Methodology Validation
- Multi-Residue Analytical Methodology Evaluation
- Use Description Scenario - Mixer/Loader/Applicator and Post-Application Workers
- Mixer/Loader/Applicator - Passive Dosimetry or Biological Monitoring
- Post-application Worker - Passive Dosimetry or Biological Monitoring
- Dislodgeable/Transferable Residue data.

4.0 Impact on the Environment

4.1 Fate and Behaviour in the Environment

Terrestrial Environment
Carbofuran is classified as relatively non-volatile under field conditions. Phototransformation is not an important route of transformation for carbofuran in soil. Transformation of carbofuran in aerobic soil appears to have resulted from a combination of hydrolysis and biotransformation. In an acidic soil (pH 5.7), carbofuran degraded with a half-life of 321 days, but in soil of pH 7.7, the half-life dropped to 149 days. The major identified transformation product was 3-ketocarbofuran. The persistence of carbofuran may decrease in soils that have been previously treated with carbofuran because of microbial adaptations. No information was available addressing the soil biotransformation of carbofuran under anaerobic conditions. Soil adsorption studies indicate that

carbofuran has a high to very high mobility in soils. K_{oc} values ranged from 10 to 63 in a variety of soils. Carbofuran was shown to be mobile in soil column leaching studies with 33 to 78% of the radioactivity in the aged soils collected in the leachate. Carbofuran was the major extractable residue in both the aged soils and the leachate. Carbofuran would be considered non-persistent to moderately persistent from field soil dissipation studies conducted in the U.S. according to the classification of Goring et al. (1975).

Aquatic Environment
The reported solubility of carbofuran in water (700 mg/L at 25 °C), would classify it as very soluble. Carbofuran is stable to hydrolysis at pHs < 6, but becomes increasingly susceptible to hydrolysis as the pH increases, hydrolyzing rapidly at alkaline pHs (half-lives of less than a day). Phototransformation is an important route of transformation for carbofuran in shallow clear water. Biotransformation was an important route of transformation in aquatic habitats under aerobic conditions. The major transformation product formed in aquatic systems was carbofuran phenol. Biotransformation was also a route of transformation in aquatic systems under anaerobic conditions, however degradation may not have been due strictly to anaerobic metabolic processes, hydrolysis may have also contributed. The major transformation product was carbofuran phenol and was predominantly associated with the sediment fraction. In alkaline environments, carbofuran appears to have a low potential to accumulate in fish.

Environmental fate data for carbofuran are summarized in Table 1 of Appendix IX.

4.2 Effects on Non-target Organisms

The environmental risk assessment integrates the environmental exposure and ecotoxicology information to estimate the potential for adverse effects on non-target species. This integration is achieved by comparing exposure concentrations with concentrations at which adverse effects occur. Estimated environmental exposure concentrations (EECs) are concentrations of pesticide in various environmental media, such as food, water, soil and air. The EECs are estimated using standard models which take into consideration the application rate(s), chemical properties and environmental fate properties, including the dissipation of the pesticide between applications. Ecotoxicology information includes acute and chronic toxicity data for various organisms or groups of organisms from both terrestrial and aquatic habitats including invertebrates, vertebrates, and plants. Toxicity endpoints used in risk assessments may be adjusted to account for potential differences in species sensitivity as well as varying protection goals (i.e. protection at the community, population, or individual level).

Initially, a screening level risk assessment is performed to identify pesticides and/or specific uses that do not pose a risk to non-target organisms, and to identify those groups of organisms for which there may be a potential risk. The screening level risk assessment uses simple methods, conservative exposure scenarios (e.g. direct application at a maximum cumulative application rate) and sensitive toxicity endpoints. A risk quotient (RQ) is calculated by dividing the exposure estimate by an appropriate toxicity value (RQ = exposure/toxicity), and the risk quotient is then compared to the level of concern (LOC = 1). If the screening level risk quotient is below the level of concern, the risk is considered negligible and no further risk characterization is necessary. If

the screening level risk quotient is equal to or greater than the level of concern, then a refined risk assessment is performed to further characterize the risk. A refined assessment takes into consideration more realistic exposure scenarios (such as drift to non-target habitats) and might consider different toxicity endpoints. Refinements may include further characterization of risk based on exposure modeling, monitoring data, results from field or mesocosm studies, and probabilistic risk assessment methods. Refinements to the risk assessment may continue until the risk is adequately characterized or no further refinements are possible.

4.2.1 Effects on Terrestrial Organisms

A risk assessment of carbofuran to terrestrial organisms was based upon an evaluation of toxicity data for the following (Table 2, Appendix IX):

- Three earthworm species, one bee species (acute exposure)
- Fifteen bird and one mammal species representing vertebrates (acute, dietary, reproduction exposure)

A summary of terrestrial toxicity data for carbofuran is presented in Table 2 (Appendix IX). For the assessment of risk, toxicity endpoints chosen from the most sensitive species were used as surrogates for the wide range of species that can be potentially exposed following treatment with carbofuran. The risk assessment for birds did not include a screening level risk assessment but instead used the conclusions of a special review conducted in Canada and the results of a refined probabilistic risk assessment conducted by the USEPA, since the label rates used for the USEPA risk assessment were similar to Canadian label rates.

The current label recommends single applications ranging from 72 to 2500 and from 72 to 1056 g a.i./ha for ground and aerial applications, respectively. Multiple applications per year are also recommended for some crops (Appendix II). For multiple applications the cumulative application rates were calculated taking into consideration the dissipation half-life of carbofuran in soil (321 days) and on foliage (3 days).

The screening level risk assessment indicated that the level of concern for earthworms and bees was exceeded at application rates of 528 g a.i./ha and higher. Table 3 (Appendix IX) summarizes the screening level risk to earthworms and bees from carbofuran.

Standard exposure scenarios on vegetation and other food sources based on correlations in Hoerger and Kenaga (1972) and Kenaga (1973) and modified according to Fletcher et al. (1994) were used to determine the concentration of pesticide in the diet of small wild mammals. Exposure is dependent on the body weight of the organism and the amount and type of food consumed. In the screening level assessment a set of generic body weights was used for mammals (15, 35, 1000 g) to represent a range of small wild mammal species. The screening level assessment used relevant food categories for each size group consisting of 100% of a particular dietary item. These items included the most conservative residue values for plants, grains/seeds, insects, and fruits. The estimated daily dietary exposure (EDE) for small wild mammals feeding on the site of carbofuran application is presented in Table 4 (Appendix IX).

The acute oral risk to small wild mammals feeding on the site of carbofuran applications are presented in Table 5 (Appendix IX). The level of concern from acute exposure is exceeded by factors ranging from 1- 380 for most generic body weights and feeding guilds of small wild mammals feeding on the site of carbofuran applications with the exception of 1 kg insectivores, granivores and frugivores following a single application at 72 g a.i./ha and 1kg insectivores and granivores following one or two applications at 132 g a.i./ha. Small wild mammals feeding on the site of carbofuran applications are therefore at risk from acute exposure to contaminated vegetation.

The chronic risk to small wild mammals feeding on the site of carbofuran applications are presented in Table 6 (Appendix IX). The level of concern from chronic exposure is exceeded by factors ranging from 1 to 190 for all the generic weights and feeding guilds following one or two applications at 528 g a.i./ha and single applications at 1132 g a.i./ha and 2500 g a.i./ha. The chronic level of concern is exceeded by factors ranging from 1.5 to 190 for all 15 and 35 g insectivores and 35 g herbivores for all of the application rates. The chronic level of concern is also exceeded by factors ranging from 3 to 102 for 1000 g herbivores at all the application rates. Small wild mammals feeding on the site of carbofuran applications are therefore at risk from chronic exposure to contaminated vegetation.

In addition, the risk associated with the consumption of food items contaminated from spray drift off the treated field was also assessed taking into consideration the spray drift deposition of spray quality of ASAE fine for ground boom (11%) and ASAE fine for aerial application (26%) at 1 m downwind from the site of application.

The acute oral risk to small wild mammals from spray drift (11%) off the site of carbofuran groundboom applications is presented in Table 8 (Appendix IX). The acute level of concern is exceeded by factors ranging from 1 to 42 for all the generic weights and feeding guilds following a single groundboom application at 2500 g a.i./ha and for most of the generic body weights and feeding guilds following a single groudboom application at 1132 g a.i./ha. The level of concern is also exceeded by factors ranging from 1 to 42 for all 35 and 1000 g herbivores for all of the groundboom application rates with the exception of 1000 g herbivores following one application at 72 g a.i./ha.

The chronic risk to small wild mammals from spray drift (11%) off the site of carbofuran groundboom applications is presented in Table 10 (Appendix IX). The chronic level of concern is exceeded by factors ranging from 1 to 30 for all the generic weights and feeding guilds with the exception of 1000 g insectivores and granivores following one ground boom application at 2500 g a.i./ha. The chronic level of concern is also exceeded by factors ranging from 1 to 30 for 35 g herbivores for all of the ground boom application rates except 72 g a.i./ha.

The acute oral risk to small wild mammals from spray drift (26 %) off the site of carbofuran aerial applications is presented in Table 9 (Appendix IX). The acute level of concern is exceeded by factors ranging from 1 to 22 for all the generic weights and feeding guilds following one or two aerial applications at 528 g a.i./ha with the exception of 1 kg insectivores and granivores.

The acute level of concern is also exceeded by factors ranging from 1 to 45 for all the generic weights and feeding guilds following single aerial applications at 1132 g a.i./ha. The acute level of concern is exceeded by factors ranging from 1.5 to 31 for all 15 and 35 g insectivores except for single aerial applications at 72 g a.i./ha. The acute level of concern is exceeded by factors ranging from 1.5 to 45 for all 35 and 1000 g herbivores at all the application rates.

The chronic risk to small wild mammals from spray drift (26 %) off the site of carbofuran aerial applications is presented in Table 11 (Appendix IX). The chronic level of concern is exceeded by factors ranging from 1 to 22 for all the generic weights and feeding guilds following single aerial applications at 1132 g a.i./ha with the exception of 1 kg insectivores and granivores. The chronic level of concern is also exceeded by factors ranging from 1.4 to 22 for 35 g and 1000 g herbivores for all of the aerial application rates except 72 g a.i./ha.

Some small wild mammals are, therefore, also at risk from acute and chronic exposure from the consumption of food items contaminated from spray drift off the site of application following both ground boom and aerial applications of carbofuran.

A re-evaluation was conducted on carbofuran by the USEPA (USEPA 2005) which used refined risk assessment methodology for the risk assessment on birds. The USEPA's Terrestrial Investigation Models (TIM v.1.0, v. 2.0, and v. 2.1) were used in this refined probabilistic risk assessment that integrates distributions of carbofuran exposure with distributions of toxicity to address bird mortality following application of carbofuran. The label rates used in the refined risk assessment were similar to label rates used in Canada, therefore the results are applicable to Canada. Some of the analysis was done using label rates for alfalfa for which carbofuran is not registered in Canada, however, the lower rate of 550 g a.i./ha is close to the rate registered in Canada for corn (240-528 g a.i./ha), potato (264-528 g a.i./ha), peppers (528 g a.i./ha), strawberries in British Columbia only (528-1200 g a.i./ha), and strawberries in Eastern Canada only (528 g a.i./ha). The conclusions of the USEPA review for flowable carbofuran were as follows:

At the higher maximum application rates modelled for foliar sprays (1120 g a.i/ha on alfalfa or corn), one-third of all bird species associated with corn and alfalfa fields were estimated to experience 60% mortality, and half of all bird species were estimated to experience 35% mortality. For the most vulnerable 10% of avian species feeding in treated fields, approximately 95 % mortality was estimated. For both corn and alfalfa aerial applications, lower application rates resulted in lower estimated mortality. However, even at the minimum application rate for corn (280 g a.i./ha), the most vulnerable 10% of avian species were estimated to experience 70% mortality, with a maximum of 86% and approximately two-thirds of the avian species were expected to experience, on average, 10% mortality. At the minimum application rate for alfalfa (140 g a.i./ha), approximately two-thirds of avian species were estimated to experience 10% mortality, while the most vulnerable 10% of avian species were estimated to experience 40% mortality, with a maximum of 48%.

The red-winged blackbird, for which species specific toxicity data is available, is expected to experience mean mortality levels in corn ranging from 24 to 64% for application rates ranging from 280 g a.i./ha to 1120 g a.i./ha respectively. For some groups of red-winged blackbirds, mortality could be as high as 95%.

On average, one-third of all bird species associated with corn and alfalfa fields were estimated to experience 50% and 30% mortality, respectively, at typical application rates (foliar spray: corn 840 g a.i./ha, alfalfa 560 g a.i./ha). Based on a combination of toxicological sensitivity and exposure, the most vulnerable 10% of avian species were estimated to experience 85% and 80% mortality in corn and alfalfa, respectively. Flocks of mallard ducks foraging in an alfalfa field (single feeding event) treated at the typical application rate were estimated to experience on average 92% mortality if they foraged on the field any time between applications through at least three days post-application. Approximately a week after application, a flock landing and foraging on a single treated field was estimated to experience 84% mortality.

Evidence from field studies and incident reports support modelled estimations, showing that approved or registered agricultural use of liquid carbofuran sprays results in mortality to birds. In addition to direct avian mortality, these field studies and bird kill incident reports indicate that flowable carbofuran has the potential to cause secondary avian mortality in cases where raptors ingest prey species, such as small birds and mammals that have previously succumbed to carbofuran intoxication.

A recent Scientific Advisory Panel (SAP) concurred with the USEPA's risk conclusion that the results of the probabilistic risk assessment support the conclusion that there is risk of avian mortality in and around carbofuran treated sites (USEPA, 2008).

A special review of carbofuran which focused on the risk to birds was conducted in Canada in the early 1990's (Agriculture Canada 1993). The conclusions of the review for flowable carbofuran were as follows:

Laboratory studies indicate that a substantial fraction of an LD_{50} can be attained by songbirds feeding on contaminated grasshoppers and other invertebrates at one of the lowest registered spray rates (132 g a.i./ha). Kills of gulls (*Larus sp.*) feeding on freshly sprayed grasshoppers have been recorded. This route of exposure is also the likely explanation for the impact of carbofuran on the Burrowing Owl (*Speotyto cunicularia*). Research has shown conclusively that carbofuran applied at the grasshopper spray rate (132 g a.i./ha) has a significant impact on the survival and reproductive success of Burrowing Owls. Significant declines in nesting success and brood size were seen with increasing proximity of carbofuran spraying to the nest burrow. Information available on likely routes of exposure strongly suggests that the hazard to Burrowing Owls is in direct proportion to the availability of contaminated prey items, either invertebrates or rodent species.

Studies involving the spraying of alfalfa fields at either 550 or 1100 g a.i./ha by ground and air were carried out by the manufacturer in the United States. (The lower rate of 550 g a.i./ha is close to the rate registered in Canada for corn, potato, peppers, and strawberries in eastern Canada. Songbird mortality was recorded at both application rates, whether the insecticide was applied by air or by ground. Most of the dead birds were associated with field edges.

Further studies involved the aerial application of carbofuran to cornfields at rates of 1100 g a.i./ha for the control of the European corn borer. This rate of application is similar to the maximum rate registered in Canada on corn (528 g a.i./ha) and lower than the rates registered in Canada for sugar beets in western Canada (1123.2 g a.i./ha), and temporary emergency uses on turnips and rutabagas in British Columbia (2520 g a.i./ha). Application coverage was again very poor, with average deposits of 22 percent of applied; contamination of field edges was again documented. Despite the low measured rates of application, the spray again killed a number of songbirds.

4.2.2 Effects on Aquatic Organisms

A risk assessment of carbofuran to freshwater aquatic organisms was based upon an evaluation of toxicity data for the following (Table 2, Appendix IX):

- Four freshwater invertebrate species (acute and chronic exposure)
- Eight freshwater fish species (acute and chronic exposure)
- One freshwater algae
- Two freshwater vascular plant species
- One amphibian species
- Five estuarine/marine invertebrate species (acute and chronic exposure)
- Three estuarine/marine fish species (acute and chronic exposure)

Carbofuran is toxic to aquatic invertebrates and fish on an acute basis. Chronic effects to aquatic organisms are also expected. A summary of aquatic toxicity data for carbofuran is presented in Table 2 (Appendix IX). For the assessment of risk, toxicity endpoints chosen from the most sensitive species were used as surrogates for the wide range of species that can be potentially exposed following treatment with carbofuran.

Screening Level Assessment

The initial conservative screening level EEC calculations for aquatic systems were based on a direct application to water depths of 15 and 80 cm. The 15 cm depth was chosen to represent a temporary body of water that could be inhabited by amphibians. The 80 cm depth was chosen to represent a typical permanent water body for applications of pest control products in agriculture. The screening level risk assessment indicated that carbofuran poses both an acute and chronic risk to freshwater and estuarine/marine invertebrates and fish for most of the application rates. The level of concern was not exceeded for freshwater algae and vascular plants. The level of concern was only exceeded for amphibians at the highest application rate of 2500 g a.i./ha.

Table 7 (Appendix IX) summarize the screening level risk assessment for carbofuran to aquatic organisms.

A refined risk assessment was conducted for those taxa that exceeded the level of concern in the screening level risk assessment. Table 12 (Appendix IX) summarizes the refined risk assessment to aquatic organisms from carbofuran spray drift.

Spray Drift Refinement

The spray drift data of Wolf and Caldwell (2001) was used to determine that the maximum spray deposit into an aquatic habitat located 1 meter downwind from a field sprayed using ground boom and aerial equipment and a fine droplet size spray quality will not exceed 11% and 26% of the application rate, respectively. This information was used to re-calculate the peak concentrations in model water bodies 15 and 80 cm deep adjacent to a field where carbofuran was being applied aerially and by ground boom sprayers. The toxicology endpoints used to calculate risk quotients were the same as those used in the screening level assessment.

The acute and chronic levels of concern for freshwater aquatic invertebrates are exceeded for all use-patterns following groundboom applications by factors ranging from 1.4 to 26.5 with the exception of one application at 72 g a.i./ha. The acute and chronic levels of concern are also exceeded for all use-patterns following aerial applications by factors ranging from 1.8 to 28.3.

The level of concern for benthic invertebrates is exceeded following ground boom applications for single applications at 1132 and 2500 g a.i./ha by factors ranging from 1.5 to 3.3. The level of concern is exceeded following aerial applications for one and two applications at 528 and single applications at 1132 g a.i./ha by factors ranging from 1.6 to 3.5.

The acute level of concern for freshwater fish is exceeded for single groundboom applications at 1132 and 2500 g a.i./ha and for two groundboom applications at 528 g a.i./ha by factors ranging from 1.8 to 3.9. The acute level of concern is also exceeded for one or two aerial applications at 528 g a.i./ha and single aerial applications at 1132 g a.i./ha by factors ranging from 2.1 to 4.2.

The chronic level of concern for freshwater fish for ground boom applications is only exceeded for one application at 2500 g a.i./ha by a factor of 1.4. The chronic level of concern for aerial applications is only exceeded for one application at 1132 g a.i./ha by a factor of 1.5.

The acute level of concern for amphibians is not exceeded for one application at 2500 g a.i./ha which was the only use-pattern requiring refinement.

The acute level of concern for estuarine/marine invertebrates is exceeded by factors ranging from 2.2 - 10.4 for single groundboom applications at 528, 1132 and 2500 g a.i./ha and two groundboom applications at 528 g a.i./ha. The acute level of concern is exceeded by factors ranging from 1.3 to 11.2 for all aerial applications with the exception of one application at 72 g a.i./ha.

The chronic level of concern for estuarine/marine invertebrates is exceeded by factors ranging from 2.5 to 92.3 for all of the use-patterns of carbofuran for both groundboom and aerial applications.

The acute level of concern for estuarine/marine fish is exceeded by factors ranging from 2.2 to 10.4 for single groundboom applications at 528, 1132 and 2500 g a.i./ha and two groundboom applications at 528 g a.i./ha. The acute level of concern is exceeded by factors ranging from 1.3 to 11.2 for all aerial applications with the exception of one application at 72 g a.i./ha.

The chronic level of concern for estuarine/marine fish is exceeded by factors ranging from 2.8 to 13.2 for single groundboom applications at 528, 1132 and 2500 g a.i./ha and two applications at 528 g a.i./ha. The chronic level of concern is exceeded by factors ranging from 1.6 to 14.2 for all aerial applications with the exception of one application at 72 g a.i./ha.

Runoff Refinement

Estimated environmental concentrations (EECs) of carbofuran from runoff into a receiving water body were simulated using the PRZM/EXAMS models. The PRZM/EXAMS models simulate pesticide runoff from a treated field into an adjacent water body and the fate of a pesticide within that water body. For the Level 1 assessment, the water body consists of a 1 ha wetland with an average depth of 0.8 m and a drainage area of 10 ha.

Carbofuran is an insecticide used primarily on corn and potatoes. The maximum annual application rate for use on corn and potatoes is 2 applications of 528 g a.i./ha, with a 14 day interval. The temporary use on turnips and rutabagas (in British Columbia, 3 applications of 2500 g a.i./ha, with a 20-day interval) was also modelled.

Six standard scenarios were used to represent different regions of Canada. Eight application dates covering July and August between were modelled (The turnip use was modelled on a single scenario with application rates from 1 April until 1 June.) Deposition from spray drift was not included in the simulations, so these EECs are for the portion of the pesticide that enters the water body via runoff only. The model was run for 50 years for all scenarios. For each year of the simulation, PRZM/EXAMS calculates peak (or daily maximum) and time-averaged concentrations. The time-averaged concentrations are calculated by averaging the daily concentrations over five time periods (96 hours, 21days, 60 days, 90 days, and 1 year). The 90th percentiles over each averaging period are reported as the EECs for that period. The EECs are listed in Table 1.

Table 1: PRZM/EXAMS Runoff Modelling Results (µg a.i./L) for Carbofuran in a Water Body 0.8 m Deep, Excluding Spray Drift.

Region	EEC (µg a.i./L)					
	Peak	96-hour	21-day	60-day	90-day	Yearly
Use on corn and potatoes, 2 x 528 g a.i./ha						
Ontario	31.6	29.7	23.9	16.4	13	3.46
Quebec	28	26.7	21.7	14.6	12	3.19
Manitoba	34.9	32.8	28.4	20.6	16	4.44
New Brunswick	8.2	7.7	6.1	4	3	0.81
Prince Edward Island	31	29.2	24.1	17.2	13	3.61
British Columbia	24.7	23.2	19.4	14.4	11	3.02
Use on turnips and rutabagas, 3 x 2500 g a.i./ha (optional)						
British Columbia	117.7	111	90.9	60.6	49	14.7

The toxicology endpoints used in the screening level and refined drift assessments were used to calculate risk quotients to determine the risk from runoff to aquatic organisms in habitats adjacent to the site of carbofuran applications. The EECs with the appropriate time periods were used to calculate the risk quotients, for example 96-hour for acute endpoints and 21-day for chronic endpoints.

Table 13 (Appendix IX) summarizes the refined risk assessment to aquatic organisms from carbofuran runoff.

The acute and chronic level of concern for freshwater aquatic invertebrates is exceeded by factors ranging from 6 to 85 for all of the use-pattern scenarios. The level of concern for benthic aquatic invertebrates is exceeded by factors ranging from 2 to 11 for all of the use-pattern scenarios with the exception of the New Brunswick potato scenario.

The acute level of concern for freshwater fish is exceeded by factors ranging from 3 to 13 for all of the use-pattern scenarios with the exception of the New Brunswick potato scenario. The chronic level of concern for freshwater fish is exceeded by factors ranging from 1 to 4.7 for all of the scenarios except the New Brunswick potato scenario. The level of concern is not exceeded for amphibians for use on rutabagas in B.C.

The acute level of concern for estuarine/marine invertebrates is exceeded by factors ranging from 6 - 79 for all of the use-pattern scenarios. The chronic level of concern for estuarine/marine invertebrates is exceeded by factors ranging from 15 to 227 for all of the use-pattern scenarios.

The acute level of concern for estuarine/marine fish is exceeded by factors ranging from 2 to 34 for all of the use-pattern scenarios. The chronic level of concern for estuarine/marine fish is exceeded by factors ranging from 2 to 35 for all of the use-pattern scenarios.

Surface Water Monitoring Data Risk Assessment
The lower bound acute and chronic exposure values were estimated from monitoring data using the 95th percentiles of the maximum and arithmetic mean concentrations (including non-detects) measured in each monitoring study/site, respectively. Water monitoring, as conducted in many of the studies reviewed, involves sampling that is limited in time and space and is unlikely to detect the true maximum concentration of the analyte in question. The EECs listed in Table 14 (Appendix IX) and the toxicology endpoints used in the screening level and refined assessments were used to calculate risk quotients to determine the risk to aquatic organisms. The acute and chronic risk to aquatic organisms from the 95th percentile values for concentrations observed in surface water from monitoring data are presented in Table 14 (Appendix IX).

The acute level of concern is exceeded for freshwater invertebrates by a factor of 3.2, estuarine/marine invertebrates by a factor of 2.9 and estuarine/marine fish by a factor of 1.2. The chronic level of concern is not exceeded for any of the aquatic taxa. This analysis supports the previous aquatic risk assessment by showing that these actual "low bound" concentrations observed in Canadian surface waters from monitoring data could present a risk to freshwater and estuarine/marine invertebrates and estuarine/marine fish.

4.2.3 Incident Reports Related to the Environment

Environmental incident reports are obtained from two main sources, the Canadian pesticide incident reporting system (including both mandatory reporting from the registrant and voluntary reporting from the public and other government departments) and the USEPA Ecological Incident Information System (EIIS).

In Canada, there is at least one incident on record of waterfowl mortality resulting from exposure to contaminated puddles, following liquid carbofuran treatment of a turnip field in British Columbia. At least one Canadian field study showed a significant impact on small-mammal populations. Herbivorous species such as voles (*Microtus pennsylvanicus*) appeared to be the most affected, suggesting that exposure was primarily through grazing on contaminated vegetation.

From 1972 to 2000, 31 bird kill incidents have been reported in the United States following the use of flowable formulation carbofuran on five of the major crops where it is registered, and these are almost exclusively bird kills as a result of direct exposure. A majority (27) of the kills were reported following carbofuran use on corn and alfalfa, the two major crops where carbofuran is used. Thirty-seven species with a total of 7,300 carcasses were reported as found in twelve different states, with both primary and secondary poisonings suspected.

In the late 1990s, the technical registrant made a number of label changes to US products in order to reduce drinking water and ecological risks of concern. These included reducing application rates and numbers of applications for alfalfa, cotton, corn, potatoes, soybeans, sugarcane, and sunflowers. The USEPA therefore evaluated incidents that have occurred since 1998. Since 1998, there have been 47 carbofuran incidents reported in USEPA's Ecological Incident Information System (EIIS). Four of these incidents were from registered uses:

1) 1998 in PA, use on corn (flowable), 2 grackles
2) 1998 in PA, use on corn (flowable), 12 grackles
3) 2000 in NM, use on alfalfa (flowable), 800-1200 snow geese and ducks, and
4) 2000 in CA, use on alfalfa (flowable), 4 bee hives.

The remaining incidents were from intentional misuse (28) or the legality of use was undetermined (14). Of the 47 incidents, 13 were attributed to flowable carbofuran, two were attributed to granular carbofuran, and for the remaining incidents (32) the formulation was not reported.

Additionally, three incidents since 2000 (two in 2000 and one in 2004) were reported aggregately by the registrant, and are not in the EIIS. Details are not available on these incidents.

5.0 Value

5.1 Restricted Class Products

5.1.1 Restricted Class Uses for Which Information on the Value of Carbofuran is Sought

Appendix XII lists those uses of carbofuran that the registrant continues to support but that have risk concerns as a result of this re-evaluation.

The PMRA welcomes feedback on the availability and extent of use of chemical alternatives to carbofuran for those uses and information regarding the availability, effectiveness and extent of use of non-chemical pest management practices for any of the registered uses of carbofuran. This information will allow the PMRA to refine sustainable pest management options for the listed site-pest combinations.

5.2 Domestic Class Products

There are no registered Domestic Class carbofuran products.

5.3 Value of Carbofuran

Some uses of carbofuran may require further discussion concerning their value. These concerns may relate to economics, quarantine pests, and/or the lack of viable alternatives for uses with risk concerns. Uses for which the loss of carbofuran would be detrimental are discussed below.

5.3.1 Systemic Mode of Action

Carbofuran is effective in two ways: (a) as a contact insecticide, killing target insects upon direct contact, and; (b) as an insecticide that works as a stomach poison, killing target insects upon ingestion of treated plants. Being a systemic insecticide, carbofuran is absorbed and transported throughout the plant, imparting protection to the entire plant. Systemic insecticides are effective against insects with piercing-sucking mouthparts, such as leafhoppers, spittlebugs and tarnished plant bug, as the systemic insecticide moves within the vascular tissues and into cells where these pests feed.

As a systemic insecticide which acts upon ingestion, carbofuran is effective for the control of pests that otherwise could not be targeted by contact insecticides, or non-systemic insecticides that act as a stomach poison, such as chewing insects, once they enter the host plants. For example, European corn borer larvae bore into the midrib of the leaf and migrate into the stalk of the plant or husk of the ear (corn), or feed inside the stems and fruit (pepper).

Systemic insecticides have greater flexibility of application timing than non-systemic and contact insecticides for the control of pests that feed internally upon the host. Contact insecticides and non-systemic insecticides that act by ingestion are limited to controlling pests when present on, or feeding on the surface of the host prior to their entry into the host. The application timing must be precise, to target the majority of the pest population prior to entry into the host. Non-systemic insecticides with a prolonged period of residual activity, or repeated applications of insecticides with short residual activity, may therefore be required to replace one application with a systemic insecticide.

5.3.2 Carbofuran Uses Identified With Limited Registered or Viable Alternatives

For the control of some pests in agriculture, carbofuran is the only insecticide available, or there are few viable registered alternative products to carbofuran. For detailed information regarding the value of the uses of carbofuran identified by the PMRA, see Table 5.1.

Table 5.1 Carbofuran Uses for Which no Registered Alternatives Have Been Identified; or for Which the Availability of Viable Alternatives is Limited or are Currently Under Re-evaluation.

Crop	Pest	Registered Alternatives[1] (MoA)[2]	Comments
Canola, Mustard	Red turnip beetle	NONE	No registered alternative active ingredients.
Raspberry	Bud or root weevil	1B: malathion	Malathion is currently under re-evaluation.
Strawberry	Root weevil	1B: malathion	Malathion is currently under re-evaluation.
	Strawberry weevil (blossom clipper)	3: cypermethrin, lambda-cyhalothrin	Resistance management (Eastern Canada) Carbofuran is registered for sale for use in Eastern Canada only. Carbofuran is needed for rotation with synthetic pyrethroids for resistance management purposes in Eastern Canada.
Sugar beet	Sugar beet root maggot	1B: diazinon, terbufos	No viable registered alternative active ingredients. Diazinon is applied to sugar beets as a seed treatment. Diazinon seed treatments are proposed to be phased out (PRVD2007-16). Terbufos use on sugar beet is to be phased out (RRD2004-04). The phase out date for use of terbufos on sugar beets has been extended due to lack of alternative management strategies (PMRA, 2008).
Sunflower	Sunflower beetle	2A: endosulfan 3: cypermethrin, deltamethrin, lambda-cyhalothrin	Resistance management Endosulfan is currently under re-evaluation. The preliminary risk assessment for endosulfan indicates a level of concern for workers and the environment (REV2007-13). Carbofuran (resistance MoA group 1A) is needed for rotation with the synthetic pyrethroids (resistance MoA group 3) for resistance management purposes.

Crop	Pest	Registered Alternatives[1] (MoA)[2]	Comments
Turnip, Rutabaga[3]	Root maggot	1B: diazinon, chlorpyrifos (rutabaga only)	Carbofuran was registered as an Emergency use for the 2008 growing season in British Columbia and Nova Scotia. Diazinon is applied as: 1) an in-furrow granular treatment at planting and two weeks after thinning; 2) a soil drench treatment; and 3) a foliar spray to control adult flies. Diazinon granular and foliar treatments are proposed to be phased out (PRVD2007-16). Chlorpyrifos is registered for use on rutabaga only (granular in-furrow at planting and soil drench post planting). (REV2007-1).

1 This is a list of registered alternatives only (as of August 2008). Health Canada does not endorse any of the alternatives listed. A number of the listed alternative active ingredients are in the process of being re-evaluated by the PMRA. The registration status of active ingredients under re-evaluation may change pending the final regulatory decision. For additional information, consult the *Re-evaluation Summary Table* (PMRA, 2008).

2 Insecticide and Acaricide Resistance Management Group Numbers are based on DIR 99-06, with updates from the Insecticide Resistance Action Committee (IRAC) web site: www.irac-online.org/Crop_Protection/MoA.asp#area223 1B = acetylcholinesterase inhibitors (organophosphates); 2A = gamma-aminobutyric acid (GABA)-gated chloride channel antagonists; 3 = sodium channel modulators.

3 Temporary emergency use until August 2008

5.4 Value of Carbofuran in Context to US Regulatory Activity

The USEPA reviewed the safety and benefits of all uses of carbofuran and concluded that ecological and human health risks were of concern. The USEPA plans to cancel all carbofuran registrations.

There are few crops on which carbofuran is registered for use in both the USA and Canada. These crops include: corn (field and sweet), potato, sugar beet and sunflower. Of these, there are limited alternatives for pest control on corn (field and sweet) and sunflower in both countries.

Several alternative active ingredients are registered for use in the USA, but not in Canada. It is possible that some of these active ingredients might be proposed in future as alternatives to carbofuran in Canada.

6.0 Toxic Substances Management Policy Considerations

6.1 Toxic Substances Management Policy Considerations

The management of toxic substances is guided by the federal government's *Toxic Substances Management Policy*, which puts forward a preventive and precautionary approach to deal with substances that enter the environment and could harm the environment or human health. The

policy provides decision makers with direction and sets out a science-based management framework to ensure that federal programs are consistent with its objectives. One of the key management objectives is virtual elimination from the environment of toxic substances that result predominantly from human activity and that are persistent and bioaccumulative. These substances are referred to in the policy as Track 1 substances.

During the review process, carbofuran was assessed in accordance with the PMRA Regulatory Directive DIR99-03, *The Pest Management Regulatory Agency's Strategy for Implementing the Toxic Substances Management Policy*. Substances associated with the use of carbofuran were also considered, including major transformation products formed in the environment, and contaminants in the technical product. Carbofuran and its transformation products were evaluated against the following Track 1 criteria: persistence in soil ≥182 days; persistence in water ≥182 days; persistence in sediment ≥365 days; persistence in air ≥2 days; bioaccumulation log Kow ≥5 and/or BCF ≥5000 (or BAF ≥5000). In order for carbofuran or its transformation products to meet Track 1 criteria, the criteria for both bioaccumulation and persistence (in one media) must be met. The technical product and end-use products, including formulants, were assessed against the contaminants identified in the *Canada Gazette*, Part II, Volume 139, Number 24, pages 2641–2643: *List of Pest Control Product Formulants and Contaminants of Health or Environmental Concern, Part 3 Contaminants of Health or Environmental Concern.* The PMRA has reached the following conclusions:

- Carbofuran does not meet all Track 1 criteria. Carbofuran meets the Track 1 criterion for persistence because the half-life value in soil (321 days) exceeds the Track-1 threshold (182 days). Carbofuran does not meet the Track 1 criterion for bioaccumulation, as its octanol-water partition coefficient (log K_{ow} 1.52) is below the Track 1 threshold (log K_{ow} 5.0). Although the Track 1 criterion is met for persistence, the criterion for bioaccumulation is not met, therefore, carbofuran does not meet all criteria, and is not considered a Track 1 substance.

- Carbofuran does not form any transformation products that meet the Track 1 criteria.

- There are no Track 1 contaminants in the technical product.

Therefore, the use of carbofuran is not expected to result in the entry of Track 1 substances into the environment.

6.2 Formulants and Contaminants of Health or Environmental Concern

During the review process, contaminants in the technical are compared against the list in the *Canada Gazette*. The list is used as described in the PMRA Notice of Intent NOI2005-01[7] and is based on existing policies and regulations including: DIR99-03; and DIR2006-02[8], and taking into consideration the Ozone-depleting Substance Regulations, 1998, of the *Canadian Environmental Protection Act* (substances designated under the Montreal Protocol). The PMRA has reached the following conclusions:

Technical grade carbofuran does not contain any contaminants of health or environmental concern identified in the *Canada Gazette*.

7.0 Summary

7.1 Human Health and Safety

7.1.1 Occupational Risk

Risk estimates associated with applying, mixing and loading activities for certain proposed agricultural label uses are of concern even when engineering controls or personal protective equipment are used. Postapplication risks for workers were of concern for certain scenarios; mitigation measures that would diminish the risk were considered, however, the mitigation measures calculated to reduce post-application risk may be agronomically unfeasible.

7.1.2 Dietary Risk from Food

- Acute dietary risk from food-only exposure to carbofuran is of concern for all subpopulations.
- Chronic dietary risk from food-only exposure to carbofuran is not of concern for all subpopulations.

7.1.3 Dietary Risk from Drinking Water

Since acute dietary exposure exceeds the ARfD for food alone, there is concern about any additional exposure through drinking water.

7.1.4 Non-Occupational Risk

Given that there are no residential uses of carbofuran, a risk assessment for this scenario was not conducted.

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7 NOI2005-01, *List of Pest Control Product Formulants and Contaminants of Health or Environmental Concern under the New Pest Control Products Act*.

8 DIR2006-02, PMRA Formulants Policy.

7.1.5 Aggregate Risk (Food and Water)

An aggregate risk assessment combining exposure from food and drinking water was not conducted, as exposure from food alone is of concern.

7.2 Environmental Risk

The risk assessment of carbofuran indicates adverse effects on non-target terrestrial invertebrates and vertebrates and aquatic organisms some of which cannot be mitigated. There is potential that carbofuran may appear in surface water through runoff and in groundwater through leaching.

7.3 Value

Carbofuran is absorbed by the host plant, providing a systemic mode of action in addition to contact action. Carbofuran is effective both as a contact insecticide, killing target insects upon direct contact, and as an insecticide that works as a stomach poison, killing target insects upon ingestion of plant material containing carbofuran that has been is absorbed and translocated throughout the entire plant.

For canola, mustard, raspberry, strawberry and sugar beet, as well as the temporary (emergency uses) for turnip and rutabaga, there are no registered (or viable) alternative active ingredients to carbofuran for the control of certain pests.

8.0 Proposed Regulatory Action

After a re-evaluation of the insecticide carbofuran, Health Canada's Pest Management Regulatory Agency (PMRA), under the authority of the Pest Control Products Act, is proposing phase out of all products containing carbofuran in Canada based on the risks associated with human health and the environment (Section 7.0).

8.1 Residue Definition and Maximum Residue Limits

8.1.1 Residue Definition for Risk Assessment and Enforcement

The nature of the carbofuran residue is defined as the sum of carbofuran and 3-hydroxycarbofuran, expressed as carbofuran. MRLs for residues in or on food commodities are currently expressed in terms of carbofuran and 3-hydroxycarbofuran expressed as carbofuran under the *Pest Control Products Act*. For the estimation of dietary intake, the residue is defined as the sum of carbofuran, free 3-hydroxycarbofuran and conjugated 3-hydroxycarbofuran, expressed as carbofuran.

8.1.2 Maximum Residue Limits for Carbofuran in Food

In general, when the re-evaluation of a pesticide has been completed, the PMRA intends to update Canadian maximum residue limits and to remove MRLs that are no longer supported. The PMRA recognizes, however, that interested parties may want to retain an MRL in the absence of a Canadian registration to allow legal importation of treated commodities into Canada. The PMRA requires similar chemistry and toxicology data for such import MRLs as those required to support Canadian food use registrations. In addition, the Agency requires residue data that are representative of use conditions in exporting countries, in the same manner that representative residue data are required to support domestic use of the pesticide. These requirements are necessary so that the PMRA may determine whether the requested MRLs are needed and to ensure they would not result in unacceptable health risks.

MRLs for pesticides in or on food are established by Health Canada's PMRA under authority of the Pest Control Products Act. After the revocation of an MRL or where no specific MRL for a pest control product has been established, subsection B.15.002(1) of the Food and Drug Regulations applies. This requires that residues do not exceed 0.1 ppm and has been considered a general MRL for enforcement purposes. However, changes to the general MRL may be implemented in the future, as indicated in the Discussion Document DIS2006-01, *Revocation of 0.1 ppm as a General Maximum Residue Limit for Food Pesticide Residues [Regulation B.15.002(1)]*.

As indicated in Table 8.2, specific MRLs have been established for carbofuran residues in carrots, onions, peppers, potatoes, rutabagas, turnips and strawberries. Residues in all other agricultural commodities, including those approved for treatment in Canada but without a specific MRL, must not exceed the general MRL of 0.1 ppm.

To protect the Canadian food supply and to mitigate dietary risks of concern, it is proposed that all MRLs for carbofuran be amended or revoked. Notwithstanding the general MRL of 0.1 ppm, the intent of this action to amend or revoke theses MRLs is to prevent residues of carbofuran in or on foods. As noted above, changes to regulation B.15.002(1) may be implemented in the future.

A complete list of MRLs established in Canada can be found on the PMRA's MRL web page (www.hc-sc.gc.ca/cps-spc/pest/protect-proteger/food-nourriture/mrl-lmr-eng.php).

Table 8.2 Carbofuran MRLs in Canada

Commodity	Canadian MRL for Carbofuran, ppm
Carrots	0.5
Onions	0.3
Peppers	0.5
Potatoes	0.5
Rutabagas/Turnips	0.5
Strawberries	0.4

8.2 Additional Scientific Information Requested

The PMRA is seeking quantitative and/or qualitative information on the economic and social importance of carbofuran to specific industries and information on the availability and viability of alternative chemical and non-chemical pest management practices for the registered site and pest combinations for carbofuran. This information will allow the PMRA to refine our understanding of sustainable pest management options for pests currently managed by carbofuran.

List of Abbreviations

a.i.	active ingredient
ASAE	American Society of Agricultural Engineers
bw	body weight
°C	degree(s) Celsius
cm	centimetre(s)
d	day(s)
DT_{50}	dissipation time to 50% (the time required to observe a 50% decline in concentration)
DT_{90}	dissipation time to 90% (the time required to observe a 90% decline in concentration)
EC_{25}	effective concentration on 25% of the population
EC_{50}	effective concentration on 50% of the population
EDE	estimated daily exposure
EEC	estimated environmental exposure concentration
EP	end-use product
FIR	food ingestion rate
F/T/P	Canadian Federal, Provincial, and Territorial Committee
g	gram(s)
h	hour(s)
ha	hectare(s)
K_d	adsorption coefficient
kg	kilogram(s)
K_{oc}	organic carbon partition coefficient
K_{ow}	octanol–water partition coefficient
LC_{50}	lethal concentration on 50% of the population
LD_{50}	lethal dose on 50% of the population
L	litre(s)
LOC	Level of Concern
m	meter
M	minor use registration
MoA	mode of action
m/sec	metre(s) per second
µg	microgram(s)
mg	milligram(s)
mm	millimetre(s)
mL	millilitre(s)
nd	no detection
nm	nanometre(s)
NOEC	no observed effect concentration
NOEL	no observed adverse effect level
OECD	Organisation for Economic Co-operation and Development
OC	organic carbon
OM	organic matter
pH	-log10 hydrogen ion concentration

PMRA	Pest Management Regulatory Agency
RQ	risk quotient
SU	suspension
TGAI	technical grade active ingredient
TP	transformation product
URMULE	User Requested Minor Use Label Expansion
USC	Use Site Category
TSMP	Toxic Substances Management Policy
USEPA	United States Environmental Protection Agency
wk	week
Y	yes
yr	year

Appendix I Registered Carbofuran Products as of August 7, 2008[1]

Registration Number	Marketing Class	Registrant	Product Name	Formulation Type	Guarantee
19169	Technical	FMC Corporation	Carbofuran Technical	Solid	95%
10363	Restricted	FMC Corporation	Furadan 480 Flowable Systemic Insecticide	Suspension	480 g/L
10828	Restricted	Bayer CropScience Inc.	Furadan 480 F Systemic Liquid Insecticide	Suspension	480 g/L

[1] Excluding discontinued or suspended products, or products with a submission for discontinuation.

Appendix II Registered Restricted Class Uses of Carbofuran in Canada as of August 7, 2008.

Site(s)	Pest(s)	Formulation type[1]	Application methods and equipment	Application rate		Maximum number of applications per year	Minimum interval between applications (days)	Supported use[2]
				Product rate (L/ha)	Active ingredient rate (g a.i./ha)			
USC 7 Industrial oilseed and fiber crops USC 13 Terrestrial feed crops USC 14 Terrestrial food crops								
Canola (rapeseed) Mustard	flea beetle	SU	Ground: conventional application equipment Aerial	0.15	72	1	Not applicable	Y
	red turnip beetle			0.275	132			
Sunflower	sunflower beetle	SU	Ground: conventional application equipment	0.275	132	2	Not stated	Y
USC 13 Terrestrial feed crops USC 14 Terrestrial food crops								
Corn (Field, Silage), Western Canada only	European corn borer	SU	Ground: conventional application equipment Aerial	1.1	528	2	Not stated	Y
	Western and Northern corn rootworm adults			0.5	240			
Sugar beet Western Canada only	sugar beet root maggot	SU	Ground: conventional application equipment	2.34	1123.2	1	Not applicable	Y, M

Site(s)	Pest(s)	Formulation type[1]	Application methods and equipment	Application rate		Maximum number of applications per year	Minimum interval between applications (days)	Supported use[2]
				Product rate (L/ha)	Active ingredient rate (g a.i./ha)			
USC 14 Terrestrial food crops								
Corn (Sweet)	European corn borer	SU	Ground: conventional application equipment Aerial	1.1	528	2	Not stated	Y
	Western and Northern corn rootworm adults			0.5	240			
Pepper (green) Ontario only	European corn borer	SU	Ground: conventional application equipment	1.1	528	3	7	Y
Potato	Colorado potato beetle, potato flea beetle	SU	Ground: conventional application equipment	0.55-1.1	264-528	2	Not stated	Y
	potato leafhopper, tarnished plant bug			1.1	528			
Raspberry (field) British Columbia only	bud or root weevil	SU	Ground: conventional application equipment	1.1-	528-1200	1	Not applicable	Y
Strawberry British Columbia only	root weevil, spittlebug	SU	Ground: conventional application equipment	1.1-2.5	528-1200	1	Not applicable	Y
Strawberry Eastern Canada only	strawberry weevil (blossom clipper), tarnished plant bug	SU	Ground: conventional application equipment	1.1	528	1	Not applicable	Y

Site(s)	Pest(s)	Formulation type[1]	Application methods and equipment	Application rate		Maximum number of applications per year	Minimum interval between applications (days)	Supported use[2]
				Product rate (L/ha)	Active ingredient rate (g a.i./ha)			
USC 14 Terrestrial food crops								
TURNIP, RUTABAGA (EMERGENCY USE April 1, 2008 to August 31, 2008) British Columbia only (EMERGENCY USE May 8, 2008 to August 31, 2008) Nova Scotia only	cabbage root maggot	SU	Ground: conventional application equipment	37.5 mL product in 10 L of water per 100 m of row (i.e., 4.2 L of product in 1110 L of water per hectare with 90 cm row spacing or 5.25 L of product in 1300 L of water per hectare with 70 cm row spacing)	18 g a.i./100 m of row 2016 @ 90 cm row spacing 2520 @ 70 cm row spacing	3 (rutabaga) 1 (turnip)	20	Y

[1]SU= Suspension.

[2] Y = use is supported by the registrant; and M = use was registered as a User Requested Minor Use Label Expansion (URMULE).

Appendix III Toxicology Assessment for Carbofuran

Table 1 Toxicity Profile of Technical Carbofuran

NOTE: Depression of PChE is not considered by PMRA to be a toxicologically adverse effect; it can be viewed as a marker of exposure. Depression of EChE can be viewed as a surrogate for adverse changes in the peripheral nervous tissue in acute and some short-term studies. In studies of longer duration, depression of EChE is not considered by PMRA to be a toxicologically adverse effect.

NOTE: Effects noted below are known or assumed to occur in both sexes unless otherwise specified.

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
Metabolism/Toxicokinetic Studies			
Absorption, Distribution, Metabolism and Excretion - mice	• ^{14}C-carbofuran by gavage	**Absorption**: Approx. 50% ^{14}C-carbofuran in first 15 min, 65% by 60 min. **Distribution**: Distributed to all organs. **Metabolism**: Hydroxylation, to give 3-hydroxycarbofuran, then oxidation resulting in the formation of 3-ketocarbofuran. Breakage of the carbamate ester linkage results in liberation of phenolic derivatives and their corresponding conjugates principally glycosides. **Excretion**: 24% in urine, 6% exhaled breath in 60 minutes; 37-67% eliminated in 24 hours.	
Absorption, Distribution, Metabolism and Excretion - rats	• ^{14}C-carbofuran by gavage	**Absorption**: Rapidly absorbed from GI tract. **Distribution**: Highest level in liver. **Metabolism**: Biliary Metabolites: glucuronide conjugates of 3-hydroxycarbofuran (~60% of biliary ^{14}C) carbofuranphenol 3-hydroxycarbofuranphenol 3-keto carbofuranphenol Urinary Metabolites: 3-hydroxycarbofuran 3-ketocarbofuran carbofuranphenol 3-hydroxycarbofuran phenol 3-keto carbofuranphenol (~51%)	

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
		Excretion: In bile-duct cannulated animals: eliminated in bile (28.5%),	
		urine (65.4%), faeces (0.4%) at 48 hours. In non-bile-duct cannulated animals: eliminated in urine (92%) and feces (3%) by 120 hours with ^{14}C-ring label, eliminated in expired air (45%), urine (38%) and feces (<4%) by 32 hours with ^{14}C-carbonyl label	
Acute Toxicity Studies			
Acute Oral Toxicity - rats	• 0 - 25 mg/kg bw • 97 - 99.6%	**LD_{50} = 4.4 - 21 mg/kg bw** Clinical signs include: ↓ EChE, ↓ PChE, ↓ BChE, ataxia, salivation, lacrimation, exophthalmos, hyperpnea, cyanosis, convulsions, tremors, ↓ locomotion, lethargy, chromorhinorrhea, chromodacryorrhea. In studies with both sexes, ♀ tended to be more sensitive to lethal effects. **High oral toxicity.**	
Acute Dermal Toxicity - rats	• 10-5,000 mg/kg bw • 99.6%	**LD_{50} > 5,000 mg/kg bw (♂); 3,094 mg/kg bw (♀)** **Low dermal toxicity.**	
Acute Eye Irritation - rabbits	• 5 mg/eye • technical	Behavioural symptoms: hyperactivity, miosis (both eyes). **Minimally irritating.**	
Dermal Sensitization - guinea pigs (20♀/group)	• 0.25% intradermal injection and 50% topical application • 99.6%	Signs of systemic toxicity (apathy, difficulty breathing, tremors, muscle cramps and stretching of the hind limbs). **Non-sensitizing.**	
Subchronic Toxicity Studies			
14-day Dietary Toxicity - Beagle dogs (1/sex/group)	• 0, 18, 32, 56, 100 or 316 ppm (= 0, 0.45, 0.8, 1.4, 2.5 or 8 mg/kg bw/day) • dogs treated at 18 ppm (0.45 mg/kg bw/day) had their dose increased to 1,000 ppm (25 mg/kg bw/day) from D4-14 • 96.1 %	2.5	<ins>8.0 mg/kg bw/day</ins>: ↓ food consumption, ↓ bw (first week of treatment); <ins>25.0 mg/kg bw/day</ins>: ↓ food consumption, ↓ bw; clinical signs (muscle tremors, emesis (nonformed), salivation). EChE not inhibited at any dose, BChE not measured. **Considered supplemental due to limited group size.**

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
4-week Dietary Toxicity - Beagle dogs (4♂/group)	• 0 or 5 ppm (= 0 or 0.22 mg/kg bw/day) • 99.6%	LOAEL = 0.22	0.22 mg/kg bw/day: clinical signs (vomiting, mucus in faeces).
13-week Dietary Toxicity - Beagle dogs (4/sex/group and 2/sex/group for 4-week recovery)	• 0, 10, 70 or 500/250 ppm (= 0, 0.43, 3.1 or 22.0/10.6 mg/kg bw/day) • High-dose reduced on day 6 due to toxicity • 99.6%	LOAEL = 0.43	≥0.43 mg/kg bw/day: hyperaemia, ↑ salivation, ↓ PChE and ↓ EChE (maximal at day 1); 22.0/10.6 mg/kg bw/day: muscle spasms, ↓ motility, tachypnea, deep respiration, vomiting, ataxia (pronounced at week 1, sporadic thereafter). No effect on BChE. Full recovery of PChE and EChE.
7-day Dermal Toxicity - rabbits (#/sex/group N/S)	• 0, 100, 300 or 1,000 mg/kg bw/day, 6 hrs/day • 96.9%	LOAEL = 100	≥100 mg/kg bw/day: ↓ PChE, ↓ BChE (♂).
21-day Dermal Toxicity - NZW rabbits (#/sex/group N/S)	• 0, 10, 100, or 1,000 mg/kg bw/day, 6 hrs/day • 96.9%	10	≥100 mg/kg bw/day: ↓ BChE (♂).
Neurotoxicity Studies			
Acute Oral Cholinesterase Activity - Sprague-Dawley rats (♂/group N/S)	• 50 µg/kg bw oral carbonyl-^{14}C-carbofuran • Purity N/S	LOAEL = 0.05	↓ EChE (37% at 15 min. with recovery at 3 hrs.). Eight-hour sample collection indicated that ultimate fate was 41-47% $^{14}CO_2$, 14-15% urine, <1% faeces and 30-31% carcass.
Cholinesterase Toxicity (oral by gavage) - Pregnant Sprague Dawley rats (8♀/group)	• 0, 0.05, 0.25 or 2.5 mg/kg bw on gestation D18 • Sacrifice at 1, 5 and 24 hrs • 99%	LOAEL = 0.05	*Maternal:* ≥0.05 mg/kg bw/day:↓ blood ChE, ↓ BChE, ↓ Liver ChE; 2.5 mg/kg bw/day: tremors, salivation, miosis, dyspnea, piloerection within 5 min., high mortality. *Offspring:* ≥0.05 mg/kg bw/day: ↓ blood ChE; ≥0.25 mg/kg bw/day: ↓ Liver ChE; 2.5 mg/kg bw/day: ↓ BChE. Most pronounced effects noted at 1 hour post-dosing.

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
			Study considered supplemental.
28-day dietary Neurotoxicity range-finding study - Sprague-Dawley CD rats (5/sex/group)	• 0, 50, 200, 500, 1,000, 3,000 or 6,000 ppm (≈ 0, 2.5, 10, 25, 50, 150 or 300 mg/kg bw/day) • 98.6%	2.5	2.5 mg/kg bw/day: marginal ↓ bw gain (♂); ≥ 10 mg/kg bw/day: exophthalmia; ↓ bw gain (♂); splayed hindlimbs, marginal ↓ bw gain (♀); ≥ 25 mg/kg bw/day: tremors, ↓ locomotion, dehydration, lacrimation, staggered gait, unthriftiness; ↓ bw gain (♀); ≥ 150 mg/kg bw/day: loss of muscle control, ataxia; 300 mg/kg bw/day: mortalities (2 ♂).
90-Day Subchronic Neurotoxicity, Sprague-Dawley rats (10/sex/group)	• 0, 50, 500 or 1,000 ppm in diet (= 0, 2.4/3.1, 27.3/35.3 or 55.3/64.4 mg/kg bw/day (♂/♀)) • FOB at 4th, 8th and 13th week of treatment • 99.5%	LOAEL = 2.4	≥2.4/3.1 mg/kg bw/day: ↓ bw gain (♂); ≥27.3/35.3 mg/kg bw/day: gait impairment (staggered gait, splayed hindlimbs, ataxia, exaggerated hindlimb flexion), ↓ hindlimb grip strength; exophthalmos (♀); 55.3/64.4 mg/kg bw/day: ↓ food consumption, ↑ number of urine pools, exophthalmos; ↓ motor activity, ↓ bw gain (♀).
Developmental Neurotoxicity - Crl:CD BR rats (24♀/group)	• 0, 20, 75 or 300 ppm in diet (= 0, 1.7, 5 or 20 mg/kg bw/day), gestation D6 - lactation D10 • 99.1%	1.7	**Maternal**: ≥5 mg/kg bw/day: ↓ food consumption; ↓ bw gain. **Offspring**: ≥5 mg/kg bw/day: ↓ survival (lactation days 0-4), ↓ bw gain, developmental delays of 3 to 4 days in vaginal patency & preputial separation, brain wt decreased and auditory startle parameters affected at day 30 but not day 60, marginal delays in pinna detachment, lower incisor eruption and eye opening; 20 mg/kg bw/day: learning acquisition slowed; ↓ short and long-term memory performance but no effect on learning/memory by day 60 (♂).
Chronic Toxicity/Oncogenicity Studies			
1-Year Dietary Toxicity - Beagle dogs (6/sex/group)	• 0, 10, 20 or 500 ppm (= 0, 0.27/0.2, 0.54/0.4 or 13.5/12.0 mg/kg bw/day (♂/♀)) • High-dose animals were fed a supplemented control diet from the fifth month	0.27/0.2	≥0.54/0.4 mg/kg bw/day: ↓ PChE; one ♂ with testicular degeneration of seminiferous tubules, giant cell formation, aspermia, ↓ testes weight; 13.5/12.0 mg/kg bw/day: weight loss, tremors, salivation, vomiting, loss of body fat, ↓ RBC, ↓ Hct, ↓ Hgb, inflammatory changes in lung; one mortality, testicular degeneration of seminiferous tubules, giant cell formation, aspermia, ↓ testes weight (♂); uterine hyperplasia and hydrometra (♀).

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
	• 96.1 %		
2-year Dietary Toxicity and Carcinogenicity - CD-1 mice (100/sex/group includes 10/sex/group sacrificed at 6, 12 and 18 months)	• 0, 20, 125 or 500 ppm (= 0, 2.8, 18 or 70 mg/kg bw/day) • 95.6%	2.8	≥18 mg/kg bw/day: ↓ BChE; 70 mg/kg bw/day: ↓bw gain, ↓ food consumption. **No evidence of carcinogenicity.**
2-year Dietary Toxicity and Carcinogenicity - CD rats (90/sex/group includes 10/sex/group sacrificed at 6, 12 and 18 months)	• 0, 10, 20 or 100 ppm (≈ 0, 0.5, 1.0 or 5.0 mg/kg bw/day) • 95.6%	1.0	5.0 mg/kg bw/day: ↓ BChE, ↓ PChE, ↓ EChE, ↓ bw gain. **No evidence of carcinogenicity.**
Developmental/Reproductive Toxicity Studies			
Developmental Toxicity (oral by gavage) - CD-1 mice (10-12 ♀/group)	• 0, 0.1, 1, 5, 10 or 20 mg/kg bw/day on D6-16 • Purity N/S	Maternal/ Developmental = 5.0	**Maternal**: ≥10 mg/kg bw/day: mortality. **Developmental**: ≥10 mg/kg bw/day: ↑ fetal mortality, ↓ fetal bw; shift in rib profile (↓ incidence of 13 ribs, ↑ incidence of 14 ribs). **No evidence of teratogenicity.** **Considered supplemental due to limited group size.**
Developmental Toxicity (oral by gavage) - CD rats (10-12 ♀/group)	• 0, 0.05, 0.1, 0.5, 1.0, 3.0 or 5.0 mg/kg bw/day on D7-19 • Purity N/S	Maternal/ Developmental = 0.5	**Maternal**: ≥1.0 mg/kg bw/day: mortality, ↓ number of implantation sites. **Developmental**: ≥1.0 mg/kg bw/day: mortality, ↓ live fetuses. **No evidence of teratogenicity.** **Considered supplemental due to limited group size.**
Teratogenicity Study (oral by gavage) - rats (24♀/group)	• 0, 0.1, 0.3, or 1.0 mg/kg bw/day on D6-15 • 95.6 %	Maternal LOAEL = 0.1 Developmental NOAEL = 1.0	**Maternal**: ≥0.1 mg/kg bw/day: transient, dose-dependent clinical signs (chewing motions); ≥0.3 mg/kg bw/day: rough coats, lethargy; 1.0 mg/kg bw/day: lacrimation, salivation, trembling,

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
			convulsions, chewing motions, tremors, rough coat, lethargy; 1 mortality (♀). **Developmental**: No effects. **No evidence of teratogenicity.**
Teratology Study (oral by gavage) - rats (25♀/group)	• 0, 0.25, 0.5 or 1.2 mg/kg bw/day on D6-15 • 95.6 %	1.2	No effects. **No evidence of teratogenicity.**
Teratology Pilot Study (dietary) - rats (10♀/group)	• 0, 20, 60, 120, 160 or 200 ppm (= 0, 1.5, 4, 8, 11.0 or 13.0 mg/kg bw/day) on D6-19 • 95.6 %	Maternal = 1.5	**Maternal**: ≥1.5 mg/kg bw/day: hair loss; ≥4 mg/kg bw/day: soft stools, scabbing, ↓ bw gain, matting of hair coat, ↓ food consumption; ≥8 mg/kg bw/day: dried red matter in the nasal region. **Developmental**: No effects on limited parameters examined. **Considered supplemental based on limited group size and limited developmental parameters examined.**
Teratology Study (dietary) - rats (40♀/group)	• 0, 20, 60 or 160 ppm (= 0, 1.5, 4.4 or 11.0 mg/kg bw/day) D 6-19 with study continuing through lactation • 95.6%	Maternal NOAEL = 1.5 Offspring toxicity NOAEL = 4.4	**Maternal**: ≥4.4 mg/kg bw/day: ↓ bw gain, ↓ food consumption, anorexia, clinical signs (matting, soft stools). **Offspring**: 11.0 mg/kg bw/day: ↓ bw gain, ↑ incidence of 14th rudimentary ribs.
Teratology Study (oral by gavage) - NZW rabbits (17♀/group)	• 0, 0.2, 0.6 or 2.0 mg/kg bw/day on D6-18 • 95.6%	Maternal LOAEL = 0.2 Developmental NOAEL = 2.0	**Maternal**: ≥0.2 mg/kg bw/day: mortality; 2.0 mg/kg bw/day: signs of toxicity (trembling, loss of muscle control, salivation, sneezing, chewing motions), ↓ food consumption, ↓ water intake. **Developmental**: No effects. **No evidence of teratogenicity.**
Teratology Study (oral by gavage) - NZW rabbits	• 0, 0.12, 0.5 or 2.0 mg/kg bw/day D6-18 • 95.6%	Maternal = 0.5 Developmental =	**Maternal**: 2.0 mg/kg bw/day: 1 mortality, ↓ bw gain. **Developmental**:

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
(20♀/group)		2.0	No effects. **No evidence of teratogenicity.**
Reproduction Study (dietary) - rats (10♂/20♀/group F_0, F_1; 12♂/24♀/group F_2) (3-generation)	• 0, 20 or 100 ppm (= 0, 1.2/1.9 or 6.0/9.7 ♂/♀ mg/kg bw/day) • 95.6%	Parental, Offspring = 1.2/1.9 Reproductive = 6.0/9.7	**Parental**: 6.0/9.7 mg/kg bw/day: ↓ bw gain, ↓ food consumption. **Reproductive**: No effects. **Offspring**: 6.0/9.7 mg/kg bw/day: dehydration (F_{3a},F_{3b}), ↓ pup survival by day 4 (F_{1a}, F_{2a}, F_{3a}), ↓ bw gain.
Special Study (oral by gavage) - Druckrey rats (10♂/group)	• 0, 0.1, 0.2, 0.4 or 0.8 mg/kg bw/day, 5 days/week for 60 days • 97.2%	0.1	≥0.2 mg/kg bw/day: ↓ bw gain; ↓ wt of seminal vesicles, epididymides, ventral prostate, coagulating glands, ↓ sperm motility, ↓ sperm counts, ↑ numbers of bent or curved sperm necks & tails, testicular enzyme levels altered (↓ glucose-6-phosphate dehydrogenase & sorbitol dehydrogenase, ↑ γ-glutamyl transpeptidase & lactate dehydrogenase), moderate edema & congestion among seminiferous tubules, moderate vacuolization of Sertoli & germinal cells; ≥0.4 mg/kg bw/day: tubular atrophy, disturbed spermatogenesis, atrophy of affected cell types; 0.8 mg/kg bw/day: 7/10 mortalities, survivors showed lethargy and imbalance. **Considered supplemental.**
Reproduction Study (oral by gavage) - Druckrey rats (10♀/group)	• 0 or 0.4 mg/kg bw/day (6/group dosed throughout pregnancy) • 0, 0.2 or 0.4 mg/kg bw/day (4/group dosed during lactation D0-D21) • 97.2%	0.2	**Offspring**: 0.4 mg/kg bw/day (gestation and lactation group pups): ↓ sorbitol dehydrogenase, ↑ lactate dehydrogenase, ↑ γ-glutamyl transpeptidase, ↓ sperm motility, ↓ sperm count, ↑ sperm abnormalities, atrophied seminiferous tubules, degenerative changes to Sertoli cells. Histopathology after *in utero* exposure: individual seminiferous tubules lacked spermatogenic activity and sertoli cells frequently degenerated. **Considered supplemental.**
Effects on sperm quality and amount of ejaculate - rabbits (20♂/group)	• 1/100 or 1/10 of LD50 (unspecified doses) • Purity N/S		Overall ↓ bw, ↓ amount of sperm, ↑ abnormal sperm. **Considered supplemental due to lack of study details.**

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
Genotoxicity Studies			
Ames Test - *In vitro* Reverse mutation • *Salmonella typhimurium* TA 1535, 1537, 1538, 98, 100	• up to 10,000 µg/plate (± activation) • 80-99%		10 of 13 tests displayed a marginal response in TA1535 without activation. 1 of 13 tests displayed a positive response in TA98 and TA1538 with and without activation. **Weak Positive.**
Gene Mutations • *E. coli* W3110, *B. subtillis* H17, M45	• up to 5 mg/disc • Purity N/S		Negative.
Drosophila Sex-linked Recessive Lethal Mutation	• up to 10 ppm (feeding solution) • 97.6-98%		Negative in 3 tests.
Mitotic recombination • *S. cerevisiae*	• up to 50 mg/ml (± activation) • Purity N/S		Negative in 2 tests.
Mouse Lymphoma Mutagenesis Assay	• up to 316 µg/ml without activation; up to 1,780 µg/ml with activation • technical		Increased mutation frequency in 2 tests only at levels that were cytotoxic. **Positive.**
In vitro Chromosome Aberration Assay, CHO cells	• up to 1,000 µg/ml without activation; up to 2,500 µg/ml with activation • 96-98%		Negative in 2 tests.
In vitro Sister Chromatid Exchange, CHO cells	• up to 200 µg/ml without activation; up to 2,500 µg/ml with activation • 96-98%		Negative in 2 tests.
Unscheduled DNA Synthesis, rat hepatocytes	• up to 100 µg/ml • 97.6%		Negative.

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
Unscheduled DNA Synthesis, human fibroblasts, W138	• up to 1,000 μg/ml • Purity N/S	Negative.	
In vivo Chromosomal Aberrations - mice	• 1.9 - 5.7 mg/kg bw single dose, or 1.9 mg/kg bw/day for 4 days • 97.20%	**Positive.**	
In vivo Micronucleus Assay - mice	• 5.7 mg/kg bw single dose or 1.9 mg/kg bw/day for 4 days • 97.20%	**Positive.**	
In vivo Cytogenetics Assay - Sprague Dawley rats	• up to 10 mg/kg bw/day • 96-98%	Negative in 2 tests.	
Other Toxicity Studies (considered supplemental)			
Effects on enzymes and other biochemical parameters - rats (5/sex/group)	• 5/sex of adult or juvenile rats sacrificed for measurement of BChE and EChE for baseline • 8/sex of adult and juvenile rats treated to acute dose of carbofuran • Purity not stated		<u>Maximum ↓ EChE</u>: 30 min. after acute poisoning in both sexes in adults and juveniles. <u>Maximum ↓ BChE</u>: 60 min. after acute poisoning in both sexes in adults and juveniles. Recovery was almost complete after 4 hrs, complete recovery at 24 hrs.
Temporal Effect of Carbofuran in the Interruption of Estrous Cycle and Follicular Toxicity - Swiss albino mice (10 ♀/group)	• 0 or 1.3 mg/kg/day by gavage (in olive oil) for 5, 10, 20 and 30 days, respectively • 98%		<u>20 days</u>: bw (not statistically significant), duration of proestrus, estrus & metestrus with an in the diestrus phase (all not statistically significant), in the number of healthy follicles & an in the atretic follicles when compared to controls; <u>30 days</u>: significantly ↓ bw, significantly ↓ relative ovarian wt, significant ↓ in the number of estrous cycle & duration of proestrus, estrus & metestrus, significant ↓ in the number of healthy follicles, significant ↑ in the atretic follicles when compared to controls, the presence of few developing follicles, few small corpora lutea & many atretic follicles.
Reproductive Toxicity of	• 0, 0.4, 0.7, 1 or 1.3 mg/kg/day by gavage		<u>1.0 mg/kg/day</u>: bwg (not statistically significant), relative ovarian wt (not statistically significant), a significant in the

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
Carbofuran: Effects on Estrous Cycle and Follicles - Swiss albino mice (10 ♀/group)	(in olive oil) for 30 days, respectively • Purity N/S		number of estrous cycles & duration of proestrus, estrus & metestrus, significant in the duration of diestrus phase, an in the diestrus index, a significant in the number of healthy follicles with a significant in the number of atretic follicles, fewer developing follicles, less number of corpora lutea & many atretic follicles and the size of the ovaries was also reduced when compared to controls. <u>1.3 mg/kg/day</u>: significantly ↓ bwg, significantly ↓ relative ovarian wt, ↑ relative thyroid weight (not statistically significant). *The intoxicated mice were depressed and showed less running activity immediately after administration of
Hazardous effects of Carbofuran on pregnancy outcome - Wistar rats (6 ♀/group)	• 0, 0.2, 0.4 or 0.8 mg/kg/day by gavage (in corn oil) on gestation days 1-5 • Purity not stated		<u>0.2 mg/kg/day</u>: significantly water intake, significant RBC & WBC, overt signs of cholinergic toxicity (salivation, lachrymation, constriction of pupils, convulsions, production of loose stools & frequent urination) lasting 7-8 hrs, mild to moderate piloerection (lasting 6-8 hrs), lethargy, impairment in general locomotor activity (5 days following administration), significant number of head dips, significant incidence of bradycardia (day 5), significantly number of rears, significantly cranial length of pups (5 days after birth); <u>≥0.4 mg/kg/day</u>: significantly ↓ bwg (days 5 & 14 of pregnancy), significantly ↓ fc (day 5), ↓ number of head dips (not statistically significant), significantly ↓ number of uterine implants, implantation index, live birth index, fetal survival ratio, time taken for the appearance of fur in pups, time taken for opening of eyes in pups, significantly increased pre-implantation losses, gestation length, body length of pups, gain in body weight of pups; <u>0.8 mg/kg/day</u>: significantly ↑ MCH, 100% inhibition in several reproductive parameters (quantal pregnancy, number of uterine implants, implantation index, gestation index and pre-implantation index) therefore the other investigated reproductive parameters could not be examined.
Effects of mid-term exposure to carbofuran on pregnancy outcome - Wistar rats (6 ♀/group)	• 0, 0.2, 0.4 or 0.8 mg/kg/day by gavage (in corn oil) on gestation days 8-12 • Purity not stated		<u>0.2 mg/kg/day</u>: overt signs of marked cholinergic toxicity (excess salivation, lachrymation, pupil constriction, production of soft feces, almost colourless urine) and mild to moderate adrenergic toxicity (piloerection without expothalmia) lasting 6-8 hrs, inhibited general locomotor ability, significantly number of implants, diameter of embryos, cranio-cervical diameter of embryos & weight of pups; <u>≥0.4 mg/kg/day</u>: significantly inhibited number of rears, locomotor activity & number of head dips, significant ↑ in

Study/Species/ # of animals per group	Dose Levels/Purity of Test Material	NOAEL (mg/kg bw/day)	Results/Effects
			post-implantation loss, gestation period & the time taken for fur to appear in pups, ↓ number of implants (not statistically significant), significant ↓ in the cranio-cervical diameter of embryos, number of viable implants, litter index, fetal survival ratio, cranial length & cervico-sacral length; <u>0.8 mg/kg/day</u>: significantly ↓ WBC counts, inhibited number of rears & locomotor activity (both not statistically significant), ↑ in post-implantation loss (not statistically significant), significantly ↓ number of head dips, ↓ fetal survival ratio, cranio-cervical diameter of embryos, litter index & number of viable implants (all not statistically significant), significantly ↑ time taken by pups to open their eyes.
Metabolite Toxicity Studies			
Acute Oral Toxicity - rats	• 98% **(7-phenol)**		LD_{50} = 2,450/1,743 (♂/♀) mg/kg bw **Slight toxicity.**
Acute Oral Toxicity - rats	• 98% **(3-ketocarbofuran)**		LD_{50} = 108/93.1 (♂/♀) mg/kg bw **High toxicity.**
Acute Oral Toxicity - rats	• 98% **(3-hydroxy-7-phenol)**		LD_{50} = 1,916/1,654 (♂/♀) mg/kg bw **Slight toxicity.**
Acute Oral Toxicity - rats	• 98% **(3-keto-7-phenol)**		LD_{50} > 800 mg/kg bw
Acute Oral Toxicity - rats	• 98% **(3-hydroxycarbofuran)**		LD_{50} = 21.9/8.3 (♂/♀) mg/kg bw **High toxicity.**
90-Day Dietary Toxicity Study - Charles River CD rats (25/sex/group)	• 0, 1,000 or 3,000 ppm (0, 40.5 or 125 mg/kg bw/day) • Purity N/S **3-hydroxy-7-phenol**	40.5	125 mg/kg bw/day: ↓ BUN; ↓ urine volume, ↑ specific gravity (♂); ↓ absolute kidney wt, ↓ RBC (♀).

Table 2 Toxicology Endpoints for Use in Health Risk Assessment for Carbofuran

EXPOSURE SCENARIO	ENDPOINT	STUDY	DOSE (mg/kg bw/day)	CAF or MOE[a]
Acute Dietary	Cholinesterase inhibition	2 Acute oral rat cholinesterase activity studies	0.05	300
	ARD = 0.0002 mg/kg bw			
Chronic Dietary	Cholinesterase inhibition	2 Acute oral rat cholinesterase activity studies	0.05	300
	ADI = 0.0002 mg/kg bw/day			
Short- and Intermediate-term[b] Dermal	Cholinesterase inhibition	21-day dermal rabbit toxicity	10	100
Short- and Intermediate-term[b] Inhalation[c]	Cholinesterase inhibition	2 Acute oral rat cholinesterase activity studies	0.05	300

[a] CAF (composite assessment factor) refers to total of uncertainty and PCPA factors for dietary assessments, MOE refers to the target margin of exposure for occupational or residential assessments

[b] Relevant for all durations of exposure

[c] Since an oral NOAEL was selected, an inhalation absorption factor of 100% (default value) should be used in route-to-route extrapolation

Appendix IV Agricultural Mixer/Loader/Applicator and Post-Application Risk Assessment

Table 1 M/L/A exposure estimates and MOEs with Maximum Personal Protection Equipment [a]

Crop	Form [b]	Application Equipment [c]	Application Rates [d] (g a.i./ha)	Area treated per day [e] (ha)	Daily Exposure (µg/kg/day)		Margins of Exposure		Aggregate Risk Indices [j]
					Dermal [f]	Inhalation [g]	Dermal [h]	Inhalation [i]	
canola (rapeseed)	SU	aerial - M/L	132	400	21.94	0.12	456	414	1.06
		aerial - A			7.29	0.05	1372	947	2.57
		groundboom (c)		300	18.96	0.12	528	402	1.07
		groundboom (f)		100	6.32	0.04	1583	1205	3.20
sunflower	SU	groundboom (c)	132	300	18.96	0.12	528	402	1.07
		groundboom (f)		100	6.32	0.04	1583	1205	3.20
corn (field, silage, sweet)	SU	aerial - M/L	528	400	87.77	0.48	114	104	**0.26**
		aerial - A			29.15	0.21	343	237	**0.64**
		groundboom (c)		140	35.39	0.23	283	215	**0.57**
		groundboom (f)		80	20.22	0.13	495	377	1.00
mustard	SU	aerial - M/L	132	400	21.94	0.12	456	414	1.06
		aerial - A			7.29	0.05	1372	947	2.57
		groundboom (c)		300	18.96	0.12	528	402	1.07
		groundboom (f)		100	6.32	0.04	1583	1205	3.20
green pepper	SU	groundboom (c)	528	80	20.22	0.13	495	377	1.00
		groundboom (f)		30	7.58	0.05	1319	1004	2.67
potato	SU	groundboom	528	80	20.22	0.13	495	377	1.00
sugar beet	SU	groundboom (c)	1123	100	53.77	0.35	186	142	**0.38**
		groundboom (f)		30	16.13	0.11	620	472	1.26
raspberry	SU	groundboom (c)	1200	80	45.96	0.30	218	166	**0.44**
		groundboom (f)		30	17.23	0.11	580	442	1.17
strawberry	SU	groundboom (c)	1200	80	45.96	0.30	218	166	**0.44**
		groundboom (f)		30	17.23	0.11	580	442	1.17
rutabaga, turnip	SU	groundboom	2520	60	72.38	0.48	138	105	**0.28**

[a] Mixer/Loader: An open mixing and loading system with chemical resistant coveralls over a single layer with chemical resistant gloves and a suitable respirator. Groundboom Applicator: A closed cab with chemical resistant coveralls over a single layer (no gloves). Aerial Applicator: A single layer (long sleeved shirt and long pants), no gloves.

[b, c] SU = Suspension; M/L = Mixer/Loader; A = Applicator; Form = Formulation; groundboom (c) = custom groundboom application; groundboom (f) = farmer groundboom application.

[d] Maximum listed label rate in grams of active ingredient per hectare (g a.i./ha).

[e] Based on default assumptions and stakeholder input. See Section 3.7 for details.

[f] Where dermal exposure µg/kg/day =(unit exposure x area treated x rate)/70 kg bw.

[g] Where inhalation exposure µg/kg/day = (unit exposure x area treated x rate)/70 kg bw; includes a 90% protection factor for respirators used by Mixer/Loaders.

[h] Based on a dermal NOAEL of 10 mg/kg bw/day and a target dermal MOE of 100.
[i] Based on an oral LOAEL of 0.05 mg/kg bw/day and a target inhalation MOE of 300.
[j] Aggregate Risk Index = 1 / ((1/(Dermal MOE/Target Dermal MOE))+(1/(Inhalation MOE/Target inhalation MOE))). Shaded cells indicate calculated ARIs that do not meet the target of 1.

Table 2 Post-Application Exposure Estimates, MOEs and REIs

Crop	Applications per Year		Rates [c] (g a.i./ha)	Activity	Transfer Coefficient [d] (cm^2/hr)	DFR [e] (µg/ cm^2) at REI	Dermal Exposure [f] (µg/kg bw/day)	MOE [g]	REI [h] (days)
	Number [a]	Interval [b] (days)							
rapeseed (canola)	1	n/a	132	irrigation, scouting	1500	0.21	36.66	273	2
sunflower	2	7 [b]	132	scouting	1000	0.32	36.13	277	2
corn	2	7 [b]	528	hand harvesting, hand detasseling	17000	0.05	104.13	96	32
(field, silage, sweet)				irrigation, scouting, hand weeding	1000	0.83	94.81	105	6
mustard	1	n/a	132	irrigation, scouting	1500	0.21	36.66	273	2
green pepper	3	7	528	hand harvesting, staking, tying	1000	0.86	98.54	101	7
				irrigation, scouting	700	1.18	94.62	106	4
				thinning, hand weeding	500	1.46	83.44	120	2
potato	2	7 [b]	528	irrigation, scouting	1500	0.54	93.31	107	10
				hand weeding	300	1.26	43.35	231	2
sugar beet	1	n/a	1123	irrigation, outing	1500	0.57	97.89	102	13
				hand weeding, thinning	100	1.82	20.80	481	2
raspberry	1	n/a	1200	hand harvesting, hand pruning, training, tying, thinning	1500	0.55	94.12	106	14
				scouting, hand weeding, irrigation	500	1.75	99.98	100	3
strawberry	1	n/a	1200	pinching, pruning, training	1500	0.55	94.12	106	14
				irrigation, scouting, hand weeding, mulching	400	1.75	79.98	125	3
turnip	1	n/a	2520	hand harvesting	2500	0.36	103.38	97	25
				irrigation, scouting, hand weeding, thinning	300	2.98	102.04	98	5
rutabaga	3	20	2520	hand harvesting	2500	0.36	103.38	97	25
				irrigation, scouting, hand weeding, thinning	300	2.98	102.04	98	5

[a] The labels listed number of applications per year.
[b] A minimum interval of seven days between applications was assumed in the risk assessment for those applications where an interval was not specified.
[c] Maximum listed label rates expressed in grams a.i./hectare.
[d] Transfer coefficients are from the Science Advisory Council for Exposure Agricultural Transfer Coefficient document (Revised - August 7, 2000) and any amendments thereof (PMRA, 2004a). Surrogate TCs were used as follows: canola TCs were used to evaluate mustard; bell pepper TCs were used to evaluate green peppers; and turnip TCs were used to evaluate rutabagas).
[e] DFR is based on DFR data (see Section 3.5), at x days after application, where x is the day when an MOE ≥100 is determined or the proposed REI.
[f] Dermal exposure = DFR x TC x 8 hr / 70 kg.
[g] The resulting MOE on the recommended REI day. Based on the short and intermediate term dermal NOAEL of 10 mg/kg/day and a dermal target MOE of 100. Shaded cells indicate those calculated MOEs that failed to meet the target MOE of 100.
[h] Day at which the dermal exposure results in an MOE ≥100 or the minimum REI of 2 days as per current labels. All REIs are set following the final application.

Appendix V Dietary Exposure and Risk Estimates for Carbofuran

Table 1 Dietary Exposure and Risk Estimates for Carbofuran

Population Subgroup	Acute Dietary Exposure Risk		Chronic Dietary Exposure Risk	
	Exposure[1] (mg/kg bw) 99.9th Percentile	% ARfD	Exposure[2] (mg/kg bw/day)	% ADI
With Emergency Uses (rutabaga & turnip)				
General Population	0.001158	579	0.000027	14
All Infants (< 1 year old)	0.000695	347	0.000022	11
Children 1-2 years old	0.003002	1501	0.000070	35
Children 3-5 years old	0.002409	1204	0.000060	30
Children 6-12 years old	0.001096	548	0.000038	19
Youth 13-19 years old	0.000622	311	0.000025	12
Adults 20-49 years old	0.000974	487	0.000021	11
Adults 50+ years old	0.001387	694	0.000022	11
Females 13-49 years old	0.000861	431	0.000020	10
Without Emergency Uses (rutabaga & turnip)				
General Population	0.000359	180	0.000023	12
All Infants (< 1 year old)	0.000269	134	0.000022	11
Children 1-2 years old	0.000721	360	0.000064	32
Children 3-5 years old	0.000631	316	0.000056	28
Children 6-12 years old	0.000423	211	0.000037	18
Youth 13-19 years old	0.000291	146	0.000024	12
Adults 20-49 years old	0.000260	130	0.000019	9
Adults 50+ years old	0.000215	108	0.000015	8
Females 13-49 years old	0.000250	125	0.000018	9

[1]Acute Reference Dose (ARfD) of 0.0002 mg/ kg bw for all populations

[2]Acceptable Daily Intake (ADI) of 0.0002 mg/ kg bw/day for all populations

Appendix VI Food Residue Chemistry Summary

The PMRA based their review of the food residue chemistry on the Joint FAO/WHO Meetings on Pesticide Residues (JMPR) and USEPA evaluations as presented in the following documents:

- Joint FAO/WHO Meetings on Pesticide Residues (JMPR). Pesticide residues in food – 1997.
- Joint FAO/WHO Meetings on Pesticide Residues (JMPR). Pesticide residues in food – 2002.
- Joint FAO/WHO Meetings on Pesticide Residues (JMPR). Data Sheet on Pesticides No. 56.
- USEPA Revised Carbofuran Acute Probabilistic and Chronic Dietary Exposure Assessments for the Reregistration Eligibility Decision 2005.

The nature of the carbofuran residue in livestock and plant commodities is adequately understood based on submitted metabolism studies in rats, laying hens, lactating goats, potatoes, soya beans and corn (field corn). The nature of the carbofuran residue is defined as the sum of carbofuran and 3-hydroxycarbofuran, expressed as carbofuran.

The commonly used high pressure liquid chromatography (HPLC) method for monitoring and supervised trials involves solvent extraction of the homogenized sample, purification on a solid-phase extraction column, and determination on a reverse-phase column. A post-column reactor converts the eluted methylcarbamates to an indole, which is measured fluorimetrically. The method has a demonstrated limit of quantification (LOQ) of 0.05 mg/kg for carbofuran and 3-hydroxycarbofuran. The LOQ in milk is 0.025 mg/kg. A variation of the method involves initial hydrolysis of the homogenized sample with 0.25 N HCl to release any conjugates.

Several gas liquid chromatography (GLC) methods exist for the determination of the carbamate metabolites. A macerated sample is refluxed with 0.25 N HCl, partitioned into methylene chloride, and purified on a Florisil column. A methyl silicone capillary column with a nitrogen-phosphorus or mass spectrometric detector are used. The method may be modified by ethylating the 3-hydroxycarbofuran. Limits of determination of 0.05 to 0.10 mg/kg were demonstrated.

A Multiresidue Method is published in the US Food and Drug Administration (FDA) Pesticide Analytical Manual (PAM) for determining total residues of carbofuran in food for enforcement purposes. The 10/00 FDA PESTDATA database (PAM Volume 1, Appendix I) indicates that carbofuran and 3-hydroxy carbofuran are completely recovered (>80%) by Multiresidue Methods Section 302 (Luke Method; Protocol D) and Section 401, respectively.

The Multi-Residue Method used by the Canadian Food Inspection Agency for monitoring purposes (PMR-0010-V1.3) defines an LOQ for carbofuran and 3-hydroxycarbofuran in fruits and vegetables. At a spiking level of 0.010 ppm in apples, for carbofuran, the recovery is 94%, with an LOD of 0.0021 ppm and an LOQ of 0.0072 ppm. For 3-hydroxycarbofuran, the recovery is 89%, with an LOD of 0.0106 ppm and an LOQ of 0.0352 ppm.

Processing Studies Reviewed by USEPA:

A sugarcane processing study (USEPA: MRID 43907801, 1992) indicated that total residues of carbofuran do not concentrate, but are reduced, in sugar or molasses processed from sugarcane bearing detectable residues of carbofuran and/or its 3-hydroxy metabolite. A processing factor of

0.2X for sugar and molasses was used in the DEEM-FCID™ analyses. Also, coffee processing data (USEPA: D233094, 1997) indicated that individual residues of carbofuran metabolites of concern do not concentrate, but are reduced, in ground roast and instant coffee processed from green coffee beans. Accordingly, a processing factor of 0.1X was used for coffee in the DEEM-FCID™ analysis.

According to USEPA, it is unlikely that either carbofuran or its metabolites will concentrate in refined oil, since concentration did not occur in refined oil from any other oilseed crops including corn grain (USEPA: D195075, 1993). The half-life of carbofuran is 10 minutes at pH 9.9 and 45°C. During the processing of crude oils to refined oils, the product is subjected to sodium hydroxide treatment and 67°C temperatures (USEPA: FMC Study A97-4766, 1997). The carbamates (parent carbofuran and metabolite) are hydrolyzed to phenols during the oil refining conditions.

Field Trial Data Reviewed by USEPA:

Coffee beans: For both the chronic and acute dietary exposure analyses, anticipated residues were calculated based on field trials (USEPA: MRID 44186801 - 44186803) in which detectable residues were found in 14 of 18 samples. The anticipated residue (0.0016 ppm) was calculated based on the average field trial residue (incorporating ½ the combined LOD for parent and metabolite (0.01) for samples with non-detectable residues) adjusted for percent crop treated.

Sugarcane: For both the chronic and acute dietary exposure analyses, anticipated residues were calculated based on field trials (USEPA: MRID 43907601) in which detectable residues were found in 2 of 21 samples. The acute anticipated residue (0.0013 ppm) was calculated based on the average field trial residue (incorporating ½ the combined LOD for parent and metabolite for samples with non-detectable residues) adjusted for the maximum percent crop treated. The chronic anticipated residue (0.00026 ppm) was calculated based on the average field trial residue (incorporating ½ the combined LOD for parent and metabolite for samples with non-detectable residues) adjusted for the average percent crop treated.

Sunflower: For both the chronic and acute dietary exposure analyses, anticipated residues were calculated based on field trials (USEPA: PP#2F2683). The acute anticipated residue (0.0038 ppm) was calculated based on the average field trial residue adjusted for the maximum percent crop treated. The chronic anticipated residue (0.0015 ppm) was calculated based on the average field trial residue adjusted for the average percent crop treated.

Ruminant Feeding Studies Reviewed by USEPA:

Based on available dairy cattle feeding data, USEPA (Federal Register, Volume 69. N0 28, 2004) determined that there is no reasonable expectation of finite residues of carbofuran and its metabolites in fat, meat, and meat by-products of cattle, goat, hog, horse, and sheep. These tolerances were no longer needed under 40 CFR 180.6(a)(3).

Appendix VII Supplemental Maximum Residue Limit Information—International Situation and Trade Implications

An MRL is the maximum concentration of a pesticide that may remain in or on a food at the farm gate when the pesticide is used according to registered label directions. MRLs apply to residues on both food produced in Canada and food imported into Canada from other countries. These MRLs are established under the authority of the Pest Control Products Act, only if Health Canada's Pest Management Regulatory Agency has determined that the consumption of the pesticide residues that could remain on the food as it is eaten will not pose an unacceptable health risk. Actual residues in food as it is eaten are usually much lower than the MRL.

The United States uses the term tolerance to describe pesticide residue limits, while Canada uses the term MRL. Health Canada has worked closely with the USEPA for a number of years, and the two agencies have similar policies and standards that guide the establishment of tolerances and MRLs.

Current Canadian MRLs for carbofuran residues are listed in the table below. The residue definition is the parent compound and metabolite 3-hydroxycarbofuran. In this round of reevaluation, the PMRA did not assess the basis for the current MRLs of carbofuran. However, in order to protect the Canadian food supply and to mitigate dietary risks of concern, it is proposed that all MRLs for carbofuran be amended or revoked. Notwithstanding the general MRL of 0.1 ppm, the intent of this action to amend or revoke theses MRLs is to prevent residues of carbofuran in or on foods. As noted above, changes to regulation B.15.002(1) may be implemented in the future.

The USEPA has established tolerances for carbofuran in registered commodities. The residue definition is the parent compound and carbamate metabolites, including 3-hydroxycarbofuran. However, the USEPA are proposing the revocation of carbofuran tolerances (USEPA, 40 CFR Part 180, 07/31/2008)

The Codex maximum limit for pesticide residues (Codex MRL) is the maximum concentration of a pesticide residue (expressed as mg/kg), recommended by the Codex Alimentarius Commission to be permitted in or on food commodities and animal feeds. The Codex Alimentarius Commission was established by the Food and Agriculture Organization of the United Nations in 1961. Codex standards are considered reference standards for foods in international trade. There are currently MRLs for carbofuran in Codex. The residue definition is the parent compound and metabolite 3-hydroxycarbofuran. However, most of these MRLs have been assessed at or above the analytical method's limit of quantification (LOQ).

MRLs may vary from one country to another for a number of reasons, including differences in pesticide use patterns and the locations of the field crop trials used to generate residue chemistry data.

Appendix VIII Monitoring Data

Canadian Food Inspection Agency Monitoring Data

The National Chemical Residues Monitoring Program of the CFIA monitors the pesticide residues in domestic and imported foods. The data is compiled, evaluated and summarized in annual reports. This information is also used to determine the priorities of the ongoing monitoring program. The data allows for assessment of gradual changes in the compliance rate, the effectiveness of introduced control measures, and the estimation of consumer exposure to potentially harmful contaminants. On a daily basis, the results reported are compared to Canadian standards (e.g. MRLs). If it is found in violation, the CFIA undertakes actions deemed appropriate to the risk, up to and including product recall.

Carbofuran and 3-hydroxycarbofuran residues in food monitored by the CFIA during the period from 2000 to 2004 are summarized in the table below.

Table 1 Summary of the 2000–2004 CFIA Monitoring Program for Domestic and Imported Commodities

Commodity	Source of Data	N° of Samples	N° of Detected Samples	Range of Detected Residues (ppm)
Artichoke, globe	Import	178	0	NA
Banana	Import	1168	0	NA
Beet, sugar	Domestic	81	0	NA
	Import	211	0	NA
Blackberry	Import	153	1	0.05
Broccoli	Domestic	118	2	0.014-0.033
	Import	802	1	0.132
Carrot	Domestic	417	1	0.19
	Import	965	0	NA
Corn, sweet	Domestic	119	0	NA
	Import	351	0	NA
Cranberry	Import	82	0	NA
Cucumber	Import	1021	0	NA
Grape	Import	2178	0	NA
Melon	Import	1385	1	0.04
Kiwifruit	Import	998	1	0.51
Lettuce	Import	1176	1	0.046
Onion	Import	382	0	NA
Orange	Import	2847	2	0.03-0.09
Parsnip	Domestic	152	1	0.1
Pepper	Import	1397	1	0.52
Potato	Domestic	719	0	NA
	Import	812	0	NA

Commodity	Source of Data	N° of Samples	N° of Detected Samples	Range of Detected Residues (ppm)
Radish	Domestic	92	1	0.862
	Import	256	0	NA
Raspberry	Import	298	0	NA
Squash	Import	576	0	NA
Strawberry	Domestic	133	0	NA
	Import	433	0	NA
Tomato	Domestic	369	1	0.21
	Import	1851	1	0.01

Commodity	Source of Data	N° of Samples	N° of Detected Samples	Range of Detected Residues (ppm)
Radish	Domestic	92	1	0.862
	Import	256	0	NA
Raspberry	Import	298	0	NA
Squash	Import	576	0	NA
Strawberry	Domestic	133	0	NA
	Import	433	0	NA
Tomato	Domestic	369	1	0.21
	Import	1851	1	0.01

Appendix IX Environmental Fate and Toxicity

Table 1 Environmental Fate of Carbofuran

Study type	Test material	Study Conditions	Value or Endpoint	Comments	Major transformation products	Reference
Abiotic transformation						
Hydrolysis	^{14}C-Carbofuran	30 d	Half-life pH 6.2 >292 d pH 7.5 9 d pH 8 3 d pH 9 15 hr.	Stable under acidic conditions Rapid under alkaline conditions	carbofuran phenol	USEPA RED (2005)
Phototransformation - soil	^{14}C-Carbofuran	30 d under sunlight in California	Half-life 78 d	Not an important route of transformation		USEPA RED (2005)
Phototransformation - water	^{14}C-Carbofuran	buffered pH 7 solution, 25°C	Half-life 6 d	Important route of transformation		USEPA RED (2005)
Biotransformation						
Soil - aerobic	^{14}C-Carbofuran	Sandy loam	pH 5.7 Half-life - 321 days pH 7.7 Half-life - 149 days	persistent[1] moderately persistent[1] combination of hydrolysis and biotransformation	3-ketocarbofuran	USEPA RED (2005)
Soil - anaerobic	No information available					USEPA RED (2005)
Water/sediment - aerobic	^{14}C-Carbofuran	Sandy loam pH 4.9-5.2 Sandy loam pH increased from 5.0 - 8.2	Declined to 48% of applied after 30 d. Declined to 32% of applied after 30 d	major route of transformation hydrolysis contributed to transformation	 carbofuran phenol	USEPA RED (2005)
Water/sediment - anaerobic	^{14}C-Carbofuran	pH increased from 5.8 to 7.3 after 1 yr.	Half-life - 189 days	hydrolysis contributed to transformation	carbofuran phenol	USEPA RED (2005)

Study type	Test material	Study Conditions	Value or Endpoint	Comments	Major transformation products	Reference
		lake sediment water pH 7.9	Half-life - 5 days			
			Mobility			
Adsorption/ desorption	Carbofuran		Koc sand 63 sandy loam 62 silty clay 52 silty clay loam 36 silt loam 40 silty clay loam 30 muck 52 fine sand 10 sandy loam 31 silt loam 13 sandy loam 29 clay 36 peat 38	High to very high mobility[2]		USEPA RED (2005)
Soil column leaching	^{14}C-Carbofuran	Aged soils, pH 5.7-7.6 , 7- 39% clay	33 - 78% of radioactivity collected in leachate, carbofuran was the major residue	high potential to leach		USEPA RED (2005)
Volatility	No information			Non volatile		USEPA RED (2005)
			Field studies			
Field dissipation	Flowable concentrate Formulation not reported	Irrigated tomato field, sandy loam, pH 8.2 Field in Kansas, soil characteristics not reported	Half-life 4 -11 d Half -life > 117 d	Information lacking regarding soil characterization, no sampling with depth etc.	No information	USEPA RED (2005)

[1]classified according to the classification of Goring et al (1975)
[2]classified according to the classification of McCall et al (1981)

McCall, J.P., D.A. Laskowski, R.L. Swann and J.J. Dishburger. (1981). Measurement of sorption coefficients of organic chemicals and their use in environmental fate analysis. Pages 89 - 109 *IN* Test protocols for environmental fate and movement of toxicants. Proceedings of a symposium. Association of Official Analytical Chemists. 94th Annual Meeting, October 21 - 22, 1980 Washington, DC.

Goring, C.A.I., D.A. Laskowski, J.H. Hamaker, and R.W. Meikle. (1975) Principles of pesticide degradation in soil. Pages 135-172 in (R. Haque and V.H. Freed, eds.) Environmental dynamics of pesticides. Plenum Press, New York.

Table 2 Environmental Toxicity of Carbofuran

Organism	Study type	Species	Test material	Endpoint	Value	Reference
Terrestrial Species						
Invertebrate	Acute contact	Honey bee (*Apis mellifera*)	Carbofuran Technical	48-h LD50	**0.16 μg a.i./bee**	USEPA RED (2005)
	Acute contact	Earthworm (*Allolobophora caliginosa*)	Carbofuran Technical	14-d LC50	**0.28 mg a.i./kg soil**	USEPA RED (2005)
		Earthworm (*Eisenia foetida*)	Carbofuran Technical		3.09 - 28.3 mg a.i./kg soil	USEPA RED (2005)
		Earthworm (*Lumbricus terrestris*)	Carbofuran Technical		4.7 mg a.i./kg soil	
Birds	Acute oral	Fulvous Whistling-Duck (*Dendrocygna bicolor*)	Carbofuran Technical	LD50	0.24 mg a.i./kg bw	Agriculture Canada Special Review Carbofuran (1993)
		Mallard (*Anas platyrhynchos*)			0.37 - 0.63 mg a.i./kg bw	
		Red-winged Blackbird (*Agelaius phoeniceus*)			0.42 mg a.i./kg bw	
		Red-billed Quelea (*Quelea quelea*)			0.422-0.562 mg a.i./kg bw	
		Americal Kestrel (*Falco sparverius*)			0.6 mg a.i./kg bw	
		House Finch (*Carpodacus mexicanus*)			0.75 mg a.i./kg bw	
		House Sparrow (*Passer domesticus*)			1.33 mg a.i./kg bw	
		Rock Dove (*Columba livia*)			1.33 mg a.i./kg bw	
		Brown-headed Cowbird (*Molothrus ater*)			1.33 mg a.i./kg bw	

Organism	Study type	Species	Test material	Endpoint	Value	Reference
		Common Grackle (*Quiscalus quiscula*)			1.33 - 3.16 mg a.i./kg bw	
		Japanese Quail (*Cotumix coturnix*)			1.7- 1.9 mg a.i./kg bw	
		Eastern Screech-Owl (*Otus asio*)			1.9 mg a.i./kg bw	
		Ring-necked Pheasant (*Phasianus colchicus*)			4.2 mg a.i./kg bw	
		Northern Bobwhite (*Colinus virginianus*)			5.0 - 12 mg a.i./kg bw	
		European Starling (*Sturnus vulgaris*)			5.6 mg a.i./kg bw	
	Dietary	Mallard duck (*Anas platyrhynchos*)		LC50	79 mg a.i./kg diet	USEPA RED (2005)
	Chronic	Mallard duck (*Anas platyrhynchos*)		LOAEC	< 2.0 mg a.i./kg diet	USEPA RED (2005)
Mammals	Acute oral	Rat (*Rattus norvegicus*)	Carbofuran Technical	LD50	**6.0 mg a.i./kg bw**	HED Review
	Chronic toxicity (reproduction)	Rat (*Rattus norvegicus*)	Carbofuran Technical	NOAEC	**1.2 mg a.i./kg bw/day**	HED Review
Freshwater Organisms						
Invertebrate	Acute	waterflea (*Daphnia magna*)	Carbofuran Technical	48-h LC50	29 µg a.i./L	USEPA RED (2005)
		waterflea (*Ceriodaphnia dubia*)			**2.6 µg a.i./L**	
		crayfish (*Procambarus clarkii*)			2700 µg a.i./L	
	Chronic	waterflea (*Daphnia magna*)		21-d NOEC	9.8 µg a.i./L	

Organism	Study type	Species	Test material	Endpoint	Value	Reference
		waterflea (*Ceriodaphnia dubia*)		7-d NOEC	**1.3 µg a.i./L**	
	Benthic	midge (*Chironomus tentans*)		10-d LC50	**20.9 µg a.i./L**	
Fish	Acute	Bluegill sunfish (*Lepomis macrochirus*)	Carbofuran Technical	96-h LC50	**88 µg a.i./L**	USEPA RED (2005)
		Yellow perch (*Perca flavescens*)			120 µg a.i./L	
		Lake trout (*Salvelinus namaycush*)			164 µg a.i./L	
		Channel catfish (*Ictalurus punctatus*)			248 µg a.i./L	
		Brown trout (*Salmo trutta*)			280 µg a.i./L	
		Rainbow trout (*Oncorhynchus mykiss*)			362 µg a.i./L	
		Coho salmon (*Oncorhynchus kisutch*)			530 µg a.i./L	
		Fathead minnow (*Pimephales promelas*)			872 µg a.i /L	
	Chronic (Early Life Stage)	Rainbow trout (*Oncorhynchus mykiss*)		101-d NOEC	**24.8 µg a.i./L**	
Algae	Chronic	Green algae (*Chlorella pyrenoidosa*)	75% a.i.	8-10 week NOEC	**750 µg a.i./L**	USEPA RED (2005)
Vascular Plants	Acute	Duckweed (*Lemna minor*)	40.6% a.i.	48-h NOEC	**> 10,000 µg a.i./L**	USEPA RED (2005)
		Sago pondweed (*Potamogeton pectinatus*)				
Amphibians	Acute	Bog Frog (*Rana limnocharis*)	Formulation	48-h LC50	**11,226 µg a.i./L**	USEPA RED (2005)

Organism	Study type	Species	Test material	Endpoint	Value	Reference
Marine/Estuarine organisms						
Invertebrate	Acute	Eastern oyster (*Crassostrea virginica*)	Carbofuran Technical	96-h LC50	> 1000 µg a.i./L	USEPA RED (2005)
		Pink shrimp *(Penaeus duorarum)*			7.3 µg a.i./L	
		opossum shrimp (*Neonysis mercedis*)			**2.7 µg a.i./L**	
		copepod (*Tigriopus brevicornis*)			17.7 µg a.i./L	
	Chronic	Mysid shrimp (*Mysidopsis bahia*)		28-d NOEC	**0.4 µg a.i./L**	USEPA RED (2005)
Fish	Acute	Atlantic silverside (*Menidia menidia*) juvenile		96-h LC50	**33 µg a.i./L**	USEPA RED (2005)
		Longnose killifish (*Fundulus similis*)			> 100 µg a.i./L	
		Sheepshead minnow (*Cyprinodon variegatus*)			386 µg a.i./L	
	Chronic	Sheepshead minnow (*Cyprinodon variegatus*)		35-d NOEC	**2.6 µg a.i./L**	

Value in bold used in risk assessment.

Table 3 Screening Level Risk Assessment for Terrestrial Organisms Other than Birds and Mammals

Organism	Exposure	Endpoint value	Applic. Rate	EEC [1]	RQ[3]	LOC[4] exceeded
Invertebrates						
Earthworm	Acute Oral	LC50 ÷ 2 : 0.14 mg a.i./kg soil	72 g a.i./ha	0.03 mg a.i./kg soil	0.2	No
			132 g a.i./ha	0.06 mg a.i./kg soil	0.4	No
			528 g a.i./ha	0.23 mg a.i./kg soil	1.6	Yes
			1132 g a.i./ha	0.5 mg a.i./kg soil	3.6	Yes
			2500 g a.i./ha	1.1 mg a.i./kg soil	7.9	Yes
Bee	Acute Dermal	LD50 0.16 μg a.i./bee (0.18 kg a.i./ha[2])	72 g a.i./ha	72 g a.i./ha	0.4	No
			132 g a.i./ha	132 g a.i./ha	0.7	No
			528 g a.i./ha	528 g a.i./ha	2.9	Yes
			1132 g a.i./ha	1132 g a.i./ha	6.3	Yes
			2500 g a.i./ha	2500 g a.i./ha	13.9	Yes

1) Environmental Exposure Concentration (Soil: calculated based on a soil density of 1.5 g/cm^3, soil depth of 15 cm and the label rates taking into consideration dissipation between applications; Bee: maximum individual application rate; Parasitic wasp and vascular plants: maximum application rate not taking into consideration dissipation between applications)

2) Toxicity in μg/bee converted to the equivalent kg a.i./ha using a conversion factor of 1.12 (Atkins et al., 1981)

3) Risk Quotient (RQ) = exposure/toxicity

4) Level of Concern (LOC) = RQ = 1; a calculated RQ≥ 1 exceeds the LOC

Atkins EL; Kellum D; Atkins KW. 1981. Reducing pesticide hazards to honey bees: mortality prediction techniques and integrated management techniques. Univ Calif, Div Agric Sci, Leaflet 2883. 22 pp.

Table 4 Estimated Daily Dietary Exposure (EDE) for Small Wild Mammals Feeding on the Site of Carbofuran Application

Mammal weight (kg)	FIR (kg dw of diet/day)	Food guild	Estimated Daily Dietary Exposure (EDE) (mg a.i./kg bw/day)						
			72 g a.i./ha x 1	132 g a.i./ha x 1	528 g a.i./ha x 1	1132 g a.i./ha x 1	2500 g a.i./ha x 1	132 g a.i./ha x 2	528 g a.i./ha x 2
0.015	0.0022	insectivore	2.1	3.8	15.3	32.8	72.5	4	15.9
		granivore	0.4	0.7	2.6	5.6	12.4	0.7	2.7
		frugivore	1.1	2	7.9	17	37.4	2.1	8.2
0.035	0.0045	insectivore	1.8	3.4	13.5	28.9	63.7	3.5	14
		granivore	0.3	0.6	2.3	4.9	10.9	0.6	2.4
		frugivore	0.9	1.7	6.9	14.9	32.8	1.8	7.2
		herbivore	6.6	12	48.1	103.1	227.7	12.5	50
1	0.0687	insectivore	0.2	0.3	1.2	2.6	5.8	0.3	1.3
		granivore	0.2	0.3	1.2	2.6	5.8	0.3	1.3
		frugivore	0.5	0.9	3.7	8	17.6	1	3.9
		herbivore	3.5	6.4	25.7	55.2	121.8	6.7	26.7

Table 5 Acute Oral Risk to Small Wild Mammals Feeding on the Site of Carbofuran Applications

Mammal weight (kg)		Application Rate/Number of applications						
		72 g a.i./ha x 1	132 g a.i./ha x 1	528 g a.i./ha x 1	1132 g a.i./ha x 1	2500 g a.i./ha x 1	132 g a.i./ha x 2	528 g a.i./ha x 2
0.015	insectivore	**3.5**	**6.3**	**25.5**	**54.7**	**120.8**	**6.7**	**26.5**
	granivore	0.7	**1.2**	**4.3**	**9.3**	**20.7**	**1.2**	**4.5**
	frugivore	**1.8**	**3.3**	**13.2**	**28.3**	**62.3**	**3.5**	**13.7**
0.035	insectivore	**3**	**5.7**	**22.5**	**48.2**	**106.2**	**5.8**	**23.3**
	granivore	0.5	**1**	**3.8**	**8.2**	**18.2**	**1**	**4**
	frugivore	**1.5**	**2.8**	**11.5**	**24.8**	**54.7**	**3**	**12**
	herbivore	**11**	**20**	**80.2**	**171.8**	**379.5**	**20.8**	**83.3**
1	insectivore	0.3	0.5	**2**	**4.3**	**9.7**	0.5	**2.2**
	granivore	0.3	0.5	**2**	**4.3**	**9.7**	0.5	**2.2**
	frugivore	0.8	**1.5**	**6.2**	**13.3**	**29.3**	**1.7**	**6.5**
	herbivore	**5.8**	**10.7**	**42.8**	**92**	**203**	**11.2**	**44.5**

Values in bold exceed level of concern.

Table 6 Chronic Risk to Small Wild Mammals Feeding on the Site of Carbofuran Applications

Mammal weight (kg)		Application Rate/Number of applications						
		72 g a.i./ha x 1	132 g a.i./ha x 1	528 g a.i./ha x 1	1132 g a.i./ha x 1	2500 g a.i./ha x 1	132 g a.i./ha x 2	528 g a.i./ha x 2
0.015	insectivore	**1.8**	**3.2**	**12.8**	**27.3**	**60.4**	**3.3**	**13.3**
	granivore	0.3	0.6	**2.2**	**4.7**	**10.3**	0.6	**2.3**
	frugivore	0.9	1.7	**6.6**	**14.2**	**31.2**	**1.8**	**6.8**
0.035	insectivore	**1.5**	**2.8**	**11.3**	**24.1**	**53.1**	**2.9**	**11.7**
	granivore	0.3	0.5	**1.9**	**4.1**	**9.1**	0.5	**2**
	frugivore	0.8	**1.4**	**5.8**	**12.4**	**27.3**	**1.5**	**6**
	herbivore	**5.5**	**10**	**40.1**	**85.9**	**189.8**	**10.4**	**41.7**
1	insectivore	0.2	0.3	**1**	**2.2**	**4.8**	0.3	**1.1**
	granivore	0.2	0.3	**1**	**2.2**	**4.8**	0.3	**1.1**
	frugivore	0.4	0.8	**3.1**	**6.7**	**14.7**	0.8	**3.3**
	herbivore	**2.9**	**5.3**	**21.4**	**46**	**102**	**5.6**	**22.3**

Values in bold exceed level of concern.

Table 7 Screening Level Risk Assessment of Carbofuran to Aquatic Organisms

Organism	Exposure	Endpoint value[1] (µg a.i./L)	Use Rate (g a.i./ha)	EEC[2] (µg a.i./L)	RQ	LOC exceeded
Freshwater Species						
waterflea *Ceriodaphnia dubia*	Acute	$LC_{50} \div 2$ (1.3 µg a.i./L)	72	9	7	Yes
			132	16.5	13	Yes
			528	66	51	Yes
			1132	142	109	Yes
			2500	313	241	Yes
waterflea *Ceriodaphnia dubia*	Chronic	NOEC = 1.3	72	9	7	Yes
			132	16.5	13	Yes
			528	66	51	Yes
			1132	142	109	Yes
			2500	313	241	Yes
midge *Chironomus tentans.*	Benthic	$LC_{50} \div 2$ (10.5 µg a.i./L)	72	9	0.9	No
			132	16.5	1.6	Yes
			528	66	6.3	Yes
			1132	142	13.5	Yes
			2500	313	29.8	Yes
Bluegill sunfish	Acute	1/10th LC_{50}	72	9	1	Yes

Organism	Exposure	Endpoint value[1] (µg a.i./L)	Use Rate (g a.i./ha)	EEC[2] (µg a.i./L)	RQ	LOC exceeded
Lepomis macrochirus		(8.8 µg a.i./L)	132	16.5	1.9	Yes
			528	66	8	Yes
			1132	142	16	Yes
			2500	313	35.6	Yes
Rainbow trout *Oncorhynchus mykiss*	Chronic	NOEC = 24.8	72	9	0.4	No
			132	16.5	0.7	No
			528	66	2.7	Yes
			1132	142	5.7	Yes
			2500	313	12.6	Yes
Green algae *Chlorella pyrenoidosa*	Chronic	NOEC = 750	72	9	0.01	No
			132	16.5	0.02	No
			528	66	0.09	No
			1132	142	0.19	No
			2500	313	0.42	No
Duckweed *Lemna minor* Pondweed *Potamogeton pectinatus*	Acute	NOEC > 10,000	72	9	0.0009	No
			132	16.5	0.002	No
			528	66	0.007	No
			1132	142	0.014	No

Organism	Exposure	Endpoint value[1] (µg a.i./L)	Use Rate (g a.i./ha)	EEC[2] (µg a.i./L)	RQ	LOC exceeded
			2500	313	0.031	No
Bog frog (*Rana limnocharis*)	Acute	1/10th LC_{50} (1122.6 µg a.i./L)	72	48	0.04	No
			132	88	0.07	No
			528	352	0.3	No
			1132	755	0.7	No
			2500	1667	1.5	Yes
Estuarine/Marine Species						
opossum shrimp *Neonysis mercedis*	Acute	LC_{50} ÷ 2 (1.4 µg a.i./L)	72	9	6.4	Yes
			132	16.5	11.8	Yes
			528	66	47.1	Yes
			1132	142	101.4	Yes
			2500	313	223.6	Yes
mysid shrimp *Mysidopsis bahia*	Chronic	NOEC = 0.4	72	9	22.5	Yes
			132	16.5	41.3	Yes
			528	66	165	Yes
			1132	142	355	Yes
			2500	313	782.5	Yes
Atlantic silverside	Acute	LC_{50} ÷ 10	72	9	2.7	Yes

Organism	Exposure	Endpoint value[1] (µg a.i./L)	Use Rate (g a.i./ha)	EEC[2] (µg a.i./L)	RQ	LOC exceeded
Menidia menidia.		(3.3 µg a.i./L)	132	16.5	5	Yes
			528	66	20	Yes
			1132	142	43.0	Yes
			2500	313	94.8	Yes
sheepshead minnow *Cyprinodon variegatus*	Chronic	**NOEC** = 2.6	72	9	3.5	Yes
			132	16.5	6.3	Yes
			528	66	25.4	Yes
			1132	142	54.6	Yes
			2500	313	120.4	Yes

1) Endpoints were divided by an Uncertainty Factor to account for varying protection goals (i.e., protection at the community, population, or individual level)
2) EEC based on a 15 cm water body depth for amphibians and a 80 cm water depth for all other aquatic organisms.

Table 8 Acute Oral Risk to Small Wild Mammals From Spray Drift (11%) off the Treated Field Following Groundboom Applications

Mammal weight (kg)		Application Rate/Number of applications						
		72 g a.i./ha x 1	132 g a.i./ha x 1	528 g a.i./ha x 1	1132 g a.i./ha x 1	2500 g a.i./ha x 1	132 g a.i./ha x 2	528 g a.i./ha x 2
0.015	insectivore	0.4	0.7	**2.8**	**6**	**13.3**	0.7	**2.9**
	granivore	0.1	0.1	0.5	**1**	**2.3**	0.1	0.5
	frugivore	0.2	0.4	**1.5**	**3.1**	**6.9**	0.4	**1.5**
0.035	insectivore	0.3	0.6	**2.5**	**5.3**	**11.7**	0.6	**2.6**

Mammal weight (kg)		Application Rate/Number of applications						
		72 g a.i./ha x 1	132 g a.i./ha x 1	528 g a.i./ha x 1	1132 g a.i./ha x 1	2500 g a.i./ha x 1	132 g a.i./ha x 2	528 g a.i./ha x 2
	granivore	0.1	0.1	0.4	0.9	**2**	0.1	0.4
	frugivore	0.2	0.3	**1.3**	**2.7**	**6**	0.3	**1.3**
	herbivore	**1.2**	**2.2**	**8.8**	**18.9**	**41.7**	**2.3**	**9.2**
1	insectivore	0.03	0.1	0.2	0.5	**1.1**	0.1	0.2
	granivore	0.03	0.1	0.2	0.5	**1.1**	0.1	0.2
	frugivore	0.09	0.2	0.7	**1.5**	**3.2**	0.2	0.7
	herbivore	0.6	**1.2**	**4.7**	**10.1**	**22.3**	**1.2**	**4.9**

Values in bold exceed level of concern.

Table 9 Acute Oral Risk to Small Wild Mammals From Spray Drift (26%) off the Treated Field Following Aerial Applications

Mammal weight (kg)		Application Rate/Number of applications					
		72 g a.i./ha x 1	**132 g a.i./ha x 1**	**528 g a.i./ha x 1**	**1132 g a.i./ha x 1**	**132 g a.i./ha x 2**	**528 g a.i./ha x 2**
0.015	insectivore	0.9	**1.6**	**6.6**	**14.2**	**1.7**	**6.9**
	granivore	0.2	0.3	**1.1**	**2.4**	0.3	**1.2**
	frugivore	0.5	0.9	**3.4**	**7.4**	0.9	**3.6**
0.035	insectivore	0.8	**1.5**	**5.9**	**12.5**	**1.5**	**6.1**
	granivore	0.1	0.3	**1**	**2.1**	0.3	**1**
	frugivore	0.4	0.7	**3**	**6.4**	0.8	**3.1**
	herbivore	**2.9**	**5.2**	**21**	**44.6**	**5.4**	**21.7**
1	insectivore	0.1	0.1	0.5	**1.1**	0.1	0.6
	granivore	0.1	0.1	0.5	**1.1**	0.1	0.6
	frugivore	0.2	0.4	**1.6**	**3.5**	0.4	**1.7**
	herbivore	**1.5**	**2.8**	**11**	**24**	**2.9**	**11.6**

Values in bold exceed level of concern.

Table 10 Chronic Risk to Small Wild Mammals From Spray Drift (11%) off the Treated Field Following Groundboom Applications

Mammal weight (kg)		Application Rate/Number of applications						
		72 g a.i./ha x 1	132 g a.i./ha x 1	528 g a.i./ha x 1	1132 g a.i./ha x 1	2500 g a.i./ha x 1	132 g a.i./ha x 2	528 g a.i./ha x 2
0.015	insectivore	0.2	0.4	**1.4**	**3**	**6.6**	0.4	**1.5**
	granivore	0.03	0.07	0.2	0.5	**1.1**	0.1	0.3
	frugivore	0.1	0.2	0.7	**1.6**	**3.4**	0.2	0.7
0.035	insectivore	0.2	0.3	**1.2**	**2.7**	**5.8**	0.3	**1.3**
	granivore	0.03	0.06	0.2	0.5	**1**	0.06	0.2
	frugivore	0.09	0.2	0.6	**1.4**	**3**	0.2	0.7
	herbivore	0.6	**1.1**	**4.4**	**9.4**	**20.9**	**1.1**	**4.6**
1	insectivore	0.02	0.03	0.1	0.2	0.5	0.03	0.1
	granivore	0.02	0.03	0.1	0.2	0.5	0.03	0.1
	frugivore	0.04	0.09	0.3	0.7	**1.6**	0.09	0.4
	herbivore	0.3	0.6	**2.4**	**5.1**	**11.2**	0.6	**2.5**

Values in bold exceed level of concern.

Table 11 Chronic Risk to Small Wild Mammals From Spray Drift (26%) off the Treated Field Following Aerial Applications

Mammal weight (kg)		Application Rate/Number of applications					
		72 g a.i./ha x 1	132 g a.i./ha x 1	528 g a.i./ha x 1	1132 g a.i./ha x 1	132 g a.i./ha x 2	528 g a.i./ha x 2
0.015	insectivore	0.5	0.8	**3.3**	**7.1**	0.9	**3.5**
	granivore	0.1	0.2	0.6	**1.2**	0.2	0.6
	frugivore	0.2	0.4	**1.7**	**3.7**	0.5	**1.8**
0.035	insectivore	0.4	0.7	**2.9**	**6.3**	0.8	**3**
	granivore	0.1	0.1	0.5	**1.1**	0.1	0.5
	frugivore	0.2	0.4	**1.5**	**3.2**	0.4	**1.6**
	herbivore	1.4	**2.6**	**10.4**	**22.3**	**2.7**	**10.8**
1	insectivore	0.1	0.1	0.3	0.6	0.1	0.3
	granivore	0.1	0.1	0.3	0.6	0.1	0.3
	frugivore	0.1	0.2	0.8	**1.7**	0.2	0.9
	herbivore	0.8	**1.4**	**5.6**	**12**	**1.5**	**5.8**

Values in bold exceed level of concern.

Table 12 Refined Risk Assessment for Aquatic Organisms (Off-field, spray drift)

Organism	Exposure	Toxicity (µg a.i./L)	Applic. Rate (g a.i./ha)	RQ = EEC[1]/Toxicity		LOC exceeded	
				11%	26%	11%	26%
Freshwater Species							
waterflea *Ceriodaphnia dubia*	Acute	$LC_{50} \div 2$ (1.3 µg a.i./L)	72	0.8	1.8	No	Yes
			132	1.4	3.4	Yes	**Yes**
			528	5.6	13.3	Yes	Yes
			1132	12	28.3	Yes	Yes
			2500	26.5	no aerial application	**Yes**	Yes
waterflea *Ceriodaphnia dubia*	Chronic	NOEC = 1.3	72	0.8	1.8	No	**Yes**
			132	1.4	3.4	Yes	Yes
			528	5.6	13.3	Yes	Yes
			1132	12	28.3	Yes	**Yes**
			2500	26.5	no aerial application	Yes	
midge *Chironomus tentans*	Benthic	$LC_{50} \div 2$ (10.5 µg a.i./L)	72	0.1	0.2	**No**	**No**
			132	0.2	0.4	No	No
			528	0.7	1.6	No	Yes
			1132	1.5	3.5	Yes	Yes

Organism	Exposure	Toxicity (µg a.i./L)	Applic. Rate (g a.i./ha)	RQ = EEC[1]/Toxicity		LOC exceeded	
				11%	26%	11%	26%
			2500	3.3	no aerial application	Yes	
Bluegill sunfish *Lepomis macrochirus*	Acute	1/10th LC_{50} (8.8 µg a.i./L)	72	0.11	0.26	**No**	**No**
			132	0.2	0.5	No	No
			528	0.9	2.1	No	Yes
			1132	1.8	4.2	Yes	Yes
			2500	3.9	no aerial application	Yes	
Rainbow trout *Oncorhynchus mykiss*	Chronic	NOEC = 24.8	72	0.04	0.1	No	No
			132	0.07	0.2	No	No
			528	0.3	0.7	No	No
			1132	0.6	1.5	No	Yes
			2500	1.4	no aerial application	Yes	

Organism	Exposure	Toxicity (µg a.i./L)	Applic. Rate (g a.i./ha)	RQ = EEC[1]/Toxicity		LOC exceeded	
				11%	26%	11%	26%
Bog frog *Rana limnocharis*	Acute	1/10th LC_{50} (1122.6 µg a.i./L)	2500	0.2	no aerial application	No	
Estuarine/Marine Species							
opossum shrimp *Neomysis mercedis*	Acute	LC_{50} ÷ 2 (1.4 µg a.i./L)	72	0.7	1.7	No	Yes
			132	1.3	3.1	Yes	Yes
			528	5.2	12.2	Yes	Yes
			1132	11.2	26.4	Yes	Yes
			2500	24.6	no aerial application	Yes	
mysid shrimp *Mysidopsis bahia*	Chronic	NOEC = 0.4	72	2.5	5.9	Yes	Yes
			132	4.5	10.7	Yes	Yes
			528	18.2	42.9	Yes	Yes
			1132	39.1	92.3	Yes	Yes
			2500	86.1	no aerial application	Yes	
Atlantic silverside *Menidia menidia.*	Acute	LC_{50} ÷ 10 (3.3 µg a.i./L)	72	0.3	0.7	No	No
			132	0.6	1.3	No	Yes
			528	2.2	5.2	Yes	Yes

Organism	Exposure	Toxicity (µg a.i./L)	Applic. Rate (g a.i./ha)	RQ = EEC[1]/Toxicity		LOC exceeded	
				11%	26%	11%	26%
			1132	4.8	11.2	Yes	Yes
			2500	10.4	no aerial application	Yes	
sheepshead minnow *Cyprinodon variegatus*	Chronic	**NOEC** = 2.6	72	0.4	0.9	No	No
			132	0.7	1.6	No	Yes
			528	2.8	6.6	Yes	Yes
			1132	6	14.2	Yes	Yes
			2500	13.2	no aerial application	Yes	

[1] EEC (15 cm depth for amphibians and 80 cm depth for all other aquatic organisms) calculated based on spray drift deposition (fine droplets) for ground boom (11%) and aerial (26%) application rate.

Table 13 Risk Assessment for Aquatic Organisms From Predicted Run-off Using PRZM/EXAMS Models

Exposure/Organism	Crop/Province	EEC (µg a.i./L)	Toxicity Endpoint (µg a.i./L)	Risk Quotient	LOC Exceeded
Freshwater Species					
Acute waterflea *Ceriodaphnia dubia*	Corn Ontario	29.7	$LC_{50} \div 2$ (1.3 µg a.i./L)	22.8	Yes
	Corn Quebec	26.7		20.5	Yes
	Potato Manitoba	32.8		25.2	Yes
	Potato New Brunswick	7.7		5.9	Yes
	Potato P.E.I.	29.2		22.5	Yes
	Potato B.C.	23.2		17.8	Yes
	Rutabaga B.C.	111		85.4	Yes
Chronic waterflea *Ceriodaphnia dubia*	Corn Ontario	29.7	NOEC = 1.3	22.8	Yes
	Corn Quebec	26.7		20.5	Yes
	Potato Manitoba	32.8		25.2	Yes
	Potato New Brunswick	7.7		5.9	Yes
	Potato P.E.I.	29.2		22.5	Yes
	Potato B.C.	23.2		17.8	Yes
	Rutabaga B.C.	111		85.4	Yes

Exposure/Organism	Crop/Province	EEC (µg a.i./L)	Toxicity Endpoint (µg a.i./L)	Risk Quotient	LOC Exceeded
Benthic midge *Chironomus tentans*	Corn Ontario	29.7	$LC_{50} \div 2$ (10.5 µg a.i./L)	**2.8**	Yes
	Corn Quebec	26.7		2.5	Yes
	Potato Manitoba	32.8		3.1	Yes
	Potato New Brunswick	7.7		0.7	No
	Potato P.E.I.	29.2		2.8	Yes
	Potato B.C.	23.2		2.2	Yes
	Rutabaga B.C.	111		10.6	Yes
Acute Bluegill sunfish *Lepomis macrochirus*	Corn Ontario	29.7	1/10th LC_{50} (8.8 µg a.i./L)	**3.4**	Yes
	Corn Quebec	26.7		3	Yes
	Potato Manitoba	32.8		3.7	Yes
	Potato New Brunswick	7.7		0.9	No
	Potato P.E.I.	29.2		3.3	Yes
	Potato B.C.	23.2		2.6	Yes
	Rutabaga B.C.	111		12.6	Yes
Chronic Rainbow trout *Oncorhynchus mykiss*	Corn Ontario	31.6	NOEC = 24.8	1.3	Yes
	Corn Quebec	28		1.1	Yes
	Potato Manitoba	34.9		1.4	Yes
	Potato New Brunswick	8.2		0.3	No
	Potato P.E.I.	31		1.3	Yes
	Potato B.C.	24.7		1	Yes
	Rutabaga B.C.	117.7		4.7	Yes

Exposure/Organism	Crop/Province	EEC (µg a.i./L)	Toxicity Endpoint (µg a.i./L)	Risk Quotient	LOC Exceeded
Acute Bog frog *Rana limnocharis*	Rutabaga B.C.	111	1/10th LC_{50} (1122.6 µg a.i./L)	0.1	No
Marine/Estuarine Species					
Acute opossum shrimp *Neomysis mercedis*	Corn Ontario	29.7	$LC_{50} \div 2$ (1.4 µg a.i./L)	**21.2**	Yes
	Corn Quebec	26.7		19.1	Yes
	Potato Manitoba	32.8		23.4	Yes
	Potato New Brunswick	**7.7**		5.5	Yes
	Potato P.E.I.	29.2		20.9	Yes
	Potato B.C.	23.2		16.6	Yes
	Rutabaga B.C.	111		79.3	Yes
Chronic mysid shrimp *Mysidopsis bahia*	Corn Ontario	23.9	NOEC = 0.4	**59.8**	Yes
	Corn Quebec	21.7		54.3	Yes
	Potato Manitoba	28.4		71	Yes
	Potato New Brunswick	6.1		15.3	Yes
	Potato P.E.I.	24.1		60.3	Yes
	Potato B.C.	19.4		48.5	Yes
	Rutabaga B.C.	90.9		227.3	Yes

Exposure/Organism	Crop/Province	EEC (µg a.i./L)	Toxicity Endpoint (µg a.i./L)	Risk Quotient	LOC Exceeded
Acute Atlantic silverside *Menidia menidia*	Corn Ontario	29.7	$LC_{50} \div 10$ (3.3 µg a.i./L)	**9**	Yes
	Corn Quebec	26.7		8.1	Yes
	Potato Manitoba	32.8		9.9	Yes
	Potato New Brunswick	7.7		2.3	Yes
	Potato P.E.I.	29.2		8.8	Yes
	Potato B.C.	23.2		7	Yes
	Rutabaga B.C.	111		33.6	Yes
Chronic sheepshead minnow *Cyprinodon variegatus*	Corn Ontario	23.9	NOEC = 2.6	**9.2**	Yes
	Corn Quebec	21.7		8.3	Yes
	Potato Manitoba	28.4		10.9	Yes
	Potato New Brunswick	6.1		2.3	Yes
	Potato P.E.I.	24.1		9.3	Yes
	Potato B.C.	19.4		7.5	Yes
	Rutabaga B.C.	90.9		35	Yes

Table 14 Acute and Chronic Risk to Aquatic Organisms From Concentrations of Carbofuran in Surface Water Estimated From Available Monitoring Data

Aquatic Taxa	EEC (µg a.i./L)*	Toxicity Endpoint (µg a.i./L)	Risk Quotient **
Freshwater Invertebrates			
Acute	4.1	1.3	**3.2**
Chronic	0.14	1.3	0.1
Benthic	0.14	10.5	0.01
Freshwater Fish			
Acute	4.1	8.8	0.5
Chronic	0.14	24.8	0.006
Freshwater Algae	4.1	750	0.005
Vascular Plants	4.1	> 10,000	0.0004
Amphibians	4.1	1123	0.004
Estuarine/Marine Invertebrates			
Acute	4.1	1.4	**2.9**
Chronic	0.14	0.4	0.4
Estuarine/Marine Fish			
Acute	4.1	3.3	**1.2**
Chronic	0.14	2.6	0.05

* 95th percentile of the maximum detected concentrations from surface water monitoring studies and 95th percentile of the mean concentration for each study site including ½ LOD for non-detects for acute and chronic, respectively

** Values in bold exceed level of concern

Appendix X Carbofuran Aquatic Ecoscenario Assessment

1.0 Introduction

The following sections provide review the estimated environmental concentrations (EECs) of carbofuran resulting from water modelling and the available water monitoring data with respect to environmental exposure.

Monitoring data and modelling estimates provide different types of information, therefore are not directly comparable. Pesticide concentrations in water are highly variable in time and location, and Canadian monitoring data usually are sparse, so comparing monitoring results to modelling is not straightforward. Despite this, these two types of data are complementary and should be considered in conjunction with each other when considering the potential exposure of aquatic organisms or to humans through drinking water.

2.0 Modelling Estimates

2.1 Aquatic Ecoscenario Assessment: Level 1 Modelling

For Level 1 aquatic ecoscenario assessment, estimated environmental concentrations (EECs) of carbofuran from runoff into a receiving water body were simulated using the PRZM/EXAMS models. The PRZM/EXAMS models simulate pesticide runoff from a treated field into an adjacent water body and the fate of a pesticide within that water body. For the Level 1 assessment, the water body consists of a 1 ha wetland with an average depth of 0.8 m and a drainage area of 10 ha.

Carbofuran is an insecticide used primarily on corn and potatoes. The maximum annual application rate for use on corn and potatoes is 2 applications of 528 g a.i./ha, with a 14 day interval. The temporary use on turnips and rutabagas in British Columbia (3 applications of 2500 g a.i./ha, with a 20 day interval) was also modelled. Application information and the main environmental fate characteristics used in the models are summarized in Table 1.

Six standard scenarios were used to represent different regions of Canada. Eight application dates covering July and August between were modelled (The turnip use was modelled on a single scenario with application rates from 1 April until 1 June.) The application date producing the largest EEC for each regional scenario is reported in Table 2. Deposition from spray drift was not included in the simulations, so these EECs are for the portion of the pesticide that enters the water body via runoff only. The model was run for 50 years for all scenarios.

Table 1 Major Model Inputs for Level 1 Assessment of Carbofuran

Type of Input	Parameter	Value
Application Information	Crop(s) to be treated	Corn, potatoes, turnips, rutabagas
	Maximum allowable application rate per year (g a.i./ha)	1056 (corn, potatoes) 7500 (turnips, rutabagas)
	Maximum rate each application (g a.i./ha)	528(corn, potatoes) 2500 (turnips, rutabagas)
	Maximum number of applications per year	2 (corn, potatoes) 3 (turnips, rutabagas)
	Minimum interval between applications (days)	14 (corn, potatoes) 20 (turnips, rutabagas)
	Method of application	ground spray
Environmental Fate Characteristics	Hydrolysis half-life at pH 7 (days)	28
	Photolysis half-life in water (days)	6
	Adsorption K_{OC} (mL/g)	30 (rounded up from 20th percentile of 12 K_{OC}, to be the same as used by USEPA)
	Aerobic soil biotransformation half-life (days)	321 (USEPA Reregistration Science Eligibility Chapter)
	Aerobic aquatic biotransformation half-life (days)	642 (no data, assumed 2 times aerobic soil half-life)
	Anaerobic aquatic biotransformation half-life (days)	Assumed stable (no data)

The EECs (Table 2) are calculated from the model output from each run as follows: For each year of the simulation, PRZM/EXAMS calculates peak (or daily maximum) and time-averaged concentrations. The time-averaged concentrations are calculated by averaging the daily concentrations over five time periods (96-hour, 21-day, 60-day, 90-day, and 1 year). The 90th percentiles over each averaging period are reported as the EECs for that period.

Table 2 Level 1 Aquatic Ecoscenario Modelling Results (μg a.i./L) for Carbofuran in a Water Body 0.8 m Deep, Excluding Spray Drift.

Region	EEC (μg a.i./L)					
	Peak	96-hour	21-day	60-day	90-day	Yearly
Use on corn and potatoes, 2 x 528 g a.i./ha						
Ontario	31.6	29.7	23.9	16.4	13	3.46
Quebec	28	26.7	21.7	14.6	12	3.19
Manitoba	34.9	32.8	28.4	20.6	16	4.44
New Brunswick	8.2	7.7	6.1	4	3	0.81
Prince Edward Island	31	29.2	24.1	17.2	13	3.61
British Columbia	24.7	23.2	19.4	14.4	11	3.02
Use on turnips and rutabagas, 3 x 2500 g a.i./ha (optional)						
British Columbia	117.7	111	90.9	60.6	49	14.7

3.0 Water

3.1 Sources of Data

A search for water monitoring data on carbofuran in Canada resulted in a number of samples with detections being reported. A request was sent to the Federal Provincial and Territorial representatives from all of the provinces and territories in Canada, requesting water monitoring data for the carbamates that are currently under re-evaluation. In addition, requests were submitted to Environment Canada, the Department of Fisheries and Oceans and the Federal Provincial and Territorial Committee on drinking water through Health Canada. A response was received by all provinces and territories indicating that either monitoring data were not available or the available data were submitted.

US databases were searched for detections of carbofuran. Data on residues present in water samples taken in the US are important to consider in the Canadian water assessment given the extensive monitoring programs that exist in the US. Runoff events, local use patterns, circumstantial hydrogeology as well as testing and reporting methods are probably more important influences on residue data rather than Northern versus Southern climate. As for the climate, if temperatures are cooler, residues may break down more slowly, on the other hand if temperatures are warmer, growing seasons may be longer and inputs may be more numerous and frequent.

Data were available from the US Geological Survey National Water Quality Assessment program (NAWQA) for both ground water and surface water, and from the Six Year Review of National Drinking Water Regulations, as part of the US National Contaminant Occurrence Database (NCOD).

3.2 Approach for Evaluation

Data from Canadian and US water monitoring studies in which carbofuran was quantified are summarized in Table 3.

Even though a drinking water assessment was not required, data from municipal water sources and groundwater, which are not considered relevant for an ecoscenario assessment but would have been included in a drinking water assessment, are included in a separate section of Table 3, for information purposes.

An important limitation of the monitoring data set is that, in many cases, the data were not accompanied with use data for carbofuran. For instance, the application rate applied, when the application occurred and weather conditions prior to sampling were not known or reported. Without this information, it is difficult to conclude if non-detects were a result of non-transport or more simply a result of inappropriate timing of sampling. In addition, because the data are sparse and concentrations vary in time and space, the maximum concentration reported is unlikely to be the absolute maximum concentration that would be observed in Canada. Factors that may result in higher concentrations being detected include application at higher rates, precipitation and some areas/soils are simply more prone to leaching and/or run off. Sampling at intervals immediately following application would increase the likelihood that the maximum concentration would be detected.

Thus, it is likely carbofuran was not used in some of the areas monitored, and that higher concentrations of carbofuran may occur in other areas not monitored. The carbofuran monitoring data likely underestimate the peak exposure because of the following limitations:

- In general, the data are sparse in both time and location. In some of the studies available, carbofuran was analyzed in samples that were taken from non-carbofuran use areas. Carbofuran use information from the areas surrounding where the samples were collected is often not available.

- Sampling in some of the studies was conducted during periods when carbofuran is not applied in Canada (i.e., October through March).

- The concentrations of carbamate pesticides in surface water are directly related to the frequency and timing of monitoring in relation to pesticide application and runoff events. Therefore, timing and frequency of sampling is likely to be the most important factor influencing the concentration detected and the frequency of detections. Samples are often taken at arbitrary time intervals (i.e., once a month, once a week) and are unlikely to capture the absolute maximum concentration of carbofuran.

The following statistics are used to interpret the information available in each dataset and are summarized in Table 3.

- The detection frequency provides an indication of how often positive detections occur within the given data set. Detection frequency is primarily determined by the limits of detection and is influenced by pesticide use patterns and application rates. Consequently, a wide range of detection frequencies is likely to be expected.

- The 95^{th} percentile concentration is calculated and reported. Maximum values should also be considered, especially when the 95^{th} percentile is not available which occurs when there are insufficient detections to calculate a 95^{th} percentile.

- The maximum concentration is reported and is used to determine the 95^{th} percentile concentration to estimate an acute exposure value.

- The arithmetic mean with non-detects considered at ½ LOD is used to determine the 95^{th} percentile concentration to estimate a chronic exposure value.

Table 3 Summary of the Monitoring Studies Available for Carbofuran

Data Source	Location		Min detection or detection limit (µg/L)	# of systems tested (or absolute number of samples)	# of systems or samples with detections	Detection frequency (%)	CONCENTRATIONS (µg/L) Mean detection	95th	Absolute Max	Arithmetic Mean Including non-detects at ½ LOD
Carbofuran Residues in Ambient Water										
PMRA 1307560	West Humber River		0.1	25	3	12	0.1	0.1	0.1	0.056
	Humber River Mouth		0.1	61	4	6.6	0.1	0.73	1	0.068
	Scarlett Woods Golf Course, Station 4		0.1	25	1	4	3	-	3	0.168
	Scarlett Woods Golf Course, Station 3		0.1	26	2	7.7	0.1	0.1	0.1	0.054
	West Don River		0.1	24	4	16.7	0.1	0.1	0.1	0.058
	Don River Mouth		0.1	60	6	10	0.1	0.1	0.1	0.055
	Wilket Creek		0.1	28	2	7.1	0.1	0.1	0.1	0.054
	Burke Brook		0.1	0	13	0	-	-	-	0.05
PMRA 1307570	rivière Yamaska	1992	0.2	10	0	0	-	-	-	0.1
	rivière Noire	1992	0.2	10	0	0	-	-	-	0.1
	rivière Noire (témoin)	1992	0.2	10	0	0	-	-	-	0.1
	rivière Blanche	1992	0.2	10	0	0	-	-	-	0.1
	rivière Saint-Zéphirin	1992	0.2	10	0	0	-	-	-	0.1
		1993	0.2	30	0	0	-	-	-	0.1
	rivière Saint-Germain	1992	0.2	24	0	0	-	-	-	0.1
		1993	0.2	33	0	0	-	-	-	0.1
	rivière Salvail	1992	0.2	24	2	8.3	0.4	0.49	0.5	0.13
		1993	0.2	33	0	0	-	-	-	0.1
	rivière Chibouet	1992	0.2	23	0	0	-	-	-	0.1
		1993	0.2	45	0	0	-	-	-	0.1
	rivière des Hurons	1992	0.2	24	0	0	-	-	-	0.1
		1993	0.2	44	4	9.1	0.33	0.4	0.4	0.12
	rivière l'Acadie	1992	0.2	10	0	0	-	-	-	0.1
		1993	0.2	30	0	0	-	-	-	0.1
	rivière de la Tortue	1993	0.2	30	0	0	-	-	-	0.1
	rivière à la Barbue	1992	0.2	76	5	6.6	0.16	0.28	0.3	0.104
		1993	0.2	43	4	9.3	0.55	1.32	1.5	0.14
	rivière Saint-Régis	1993	0.2	30	0	0	-	-	-	0.1
	rivière des Fèves	1993	0.2	26	0	0	-	-	-	0.1

Data Source	Location		Min detection or detection limit (µg/L)	# of systems tested (or absolute number of samples)	# of systems or samples with detections	Detection frequency (%)	CONCENTRATIONS (µg/L)			
							Mean detection	95th	Absolute Max	Arithmetic Mean Including non-detects at ½ LOD
PMRA 1307569	rivière Saint-Zéphirin	1994	0.02	37	0	0	-	-	-	0.01
		1995	0.02	38	0	0	-	-	-	0.01
	rivière Chibouet	1994	0.02	45	4	8.9	0.05	0.09	0.1	0.014
		1995	0.02	38	1	2.6	0.02	-	0.02	0.01
	rivière des Hurons	1994	0.02	47	18	38.3	0.13	0.52	1.0	0.06
		1995	0.02	34	14	41.2	0.27	0.81	1.3	0.12
	rivière Saint-Régis	1994	0.02	34	0	0	-	-	-	0.01
		1995	0.02	35	7	20	0.2	0.5	0.71	0.05
	rivière Saint-Esprit	1994	0.02	9	0	0	-	-	-	0.01
		1995	0.02	6	3	50	0.35	0.8	0.88	0.18
	rivière des Anges	1994	0.02	10	1	10	0.02	-	0.02	0.011
		1995	0.02	2	2	100	0.43	0.8	0.84	0.43
	rivière Bayonne	1994	0.02	9	0	0	-	-	-	0.01
	rivière Noire	1994	0.02	6	0	0	-	-	-	0.01
	rivière Yamaska	1994	0.02	8	0	0	-	-	-	0.01
		1995	0.02	2	1	50	0.1	-	0.1	0.06
	rivière Nicolet	1994	0.02	4	0	0	-	-	-	0.01
	rivière Châteauguay	1994	0.02	1	0	0	-	-	-	0.01
PMRA 1307578	Déversant du Lac Stream, Rougemont	1994	0.02	12	2	16.7	0.11	0.15	0.15	0.027
		1995	0.02	15	0	0	-	-	-	0.01
		1996	0.04	23	0	0	-	-	-	0.02
	Boffin Stream, Frelighsburgh	1994	0.02	12	0	0	-	-	-	0.01
		1995	0.02	13	0	0	-	-	-	0.01
		1996	0.04	24	0	0	-	-	-	0.02
	Abott's Corner	1994	0.02	12	0	0	-	-	-	0.01
PMRA 1307581	ruisseau Corbin	1996	0.04	17	3	17.6	0.1	0.14	0.15	0.03
		1997	0.04	40	23	57.5	1.24	4.91	8.9	0.72
	ruisseau Saint-Pierre	1996	0.04	1	1	100	0.09	-	0.09	0.09
	rivière de l'Achigan	1996	0.04	18	2	11.1	0.1	0.15	0.16	0.03
		1997	0.04	29	3	10.3	0.12	0.24	0.26	0.03

Data Source	Location		Min detection or detection limit (μg/L)	# of systems tested (or absolute number of samples)	# of systems or samples with detections	Detection frequency (%)	CONCENTRATIONS (μg/L)			
							Mean detection	95th	Absolute Max	Arithmetic Mean Including non-detects at ½ LOD
PMRA 1307568	rivière Chibouet	1996	0.04	40	0	0	-	-	-	0.02
		1997	0.04	37	0	0	-	-	-	0.02
		1998	0.04	42	1	2.4	0.04	-	0.04	0.02
	rivière des Hurons	1996	0.04	41	17	41.5	0.37	1.5	1.9	0.16
		1997	0.04	39	9	23.1	0.19	0.47	0.59	0.06
		1998	0.04	45	19	42.2	0.10	0.23	0.47	0.05
	rivière Saint-Régis	1996	0.04	41	8	19.5	0.46	1.29	1.5	0.11
		1997	0.04	40	5	12.5	0.19	0.39	0.41	0.04
		1998	0.04	51	2	3.9	0.26	0.43	0.45	0.03
	rivière Saint-Zéphirin	1996	0.04	39	0	0	-	-	-	0.02
		1997	0.04	39	0	0	-	-	-	0.02
		1998	0.04	48	0	0	-	-	-	0.02
	rivière Yamaska	1996	0.04	17	0	0	-	-	-	0.02
		1997	0.04	8	0	0	-	-	-	0.02
		1998	0.04	49	2	4.1	0.04	0.04	0.04	0.02
PMRA 1307571	rivière Chibouet	1999	0.05	43	0	0	-	-	-	0.025
		2000	0.06	40	0	0	-	-	-	0.03
		2001	0.07	46	0	0	-	-	-	0.035
	rivière des Hurons	1999	0.05	45	5	11.1	0.68	2.23	2.7	0.1
		2000	0.06	42	2	4.8	0.27	0.41	0.42	0.04
		2001	0.07	44	7	15.9	0.28	0.54	0.56	0.07
	rivière Saint-Régis	1999	0.05	45	0	0	-	-	-	0.025
		2000	0.06	43	1	2.3	0.51	-	0.51	0.04
		2001	0.07	44	1	2.3	0.08	-	0.08	0.04
	rivière Saint-Zéphirin	1999	0.05	46	0	0	-	-	-	0.025
		2000	0.06	43	0	0	-	-	-	0.03
		2001	0.07	46	0	0	-	-	-	0.035
	rivière Yamaska	1999	0.05	45	0	0	-	-	-	0.025
		2000	0.06	NR	-	-	-	-	-	-
		2001	0.07	46	1	2.2	0.07	-	0.07	0.04
PMRA 1398451, 1398452, 1398453	rivière Chibouet	2002	0.06	43	0	0	-	-	-	0.03
		2003	0.06	41	0	0	-	-	-	0.03
		2004	0.06	41	0	0	-	-	-	0.03
	rivière des Hurons	2002	0.06	42	3	7.1	0.34	0.62	0.67	0.052
		2003	0.06	41	5	12.2	0.11	0.14	0.14	0.04
		2004	0.06	41	3	7.3	0.14	0.15	0.15	0.038
	rivière Saint-Régis	2002	0.06	40	0	0	-	-	-	0.03
		2003	0.06	39	0	0	-	-	-	0.03
		2004	0.06	39	1	2.6	0.18	-	0.18	0.034
	rivière Saint-Zéphirin	2002	0.06	42	0	0	-	-	-	0.03
		2003	0.06	39	0	0	-	-	-	0.03
		2004	0.06	39	0	0	-	-	-	0.03

Data Source	Location		Min detection or detection limit (µg/L)	# of systems tested (or absolute number of samples)	# of systems or samples with detections	Detection frequency (%)	CONCENTRATIONS (µg/L)			
							Mean detection	95th	Absolute Max	Arithmetic Mean Including non-detects at ½ LOD
PMRA 1403269, 1311110, 1311111, 1311112	Yamaska, Nicolet and Saint-François Rivers	2003-2004	0.06	81	0	0	-	-	-	0.03
	Saint-Lawrence at Port Saint-François and at Lévis	2003-2004	0.003	39	0	0	-	-	-	0.0015
	Streams in Prince Edward Island	2003	NR	27	1	3.7	0.03	-	0.03	-
		2004	0.05	15	1	6.7	0.59	-	0.59	0.063
		2005	NR	40	0	0	-	-	-	-
	Streams in New Brunswick	2003	NR	23	0	0	-	-	-	-
		2004	0.04	18	0	0	-	-	-	0.02
		2005	NR	15	0	0	-	-	-	-
	Streams in Nova Scotia	2004	0.04	19	0	0	-	-	-	0.02
		2005	NR	29	0	0	-	-	-	-
PMRA 1311130	Manitoba (1995-2001)		0.2-10	922	0	0	-	-	-	0.1
PMRA 1311131	Manitoba (2001-2003)		0.2	283	0	0	-	-	-	0.1
PMRA 1311126	Envirodat database PEI freshwater		0.001	32	0	0	-	-	-	0.0005
	Envirodat database PEI estuarine water		0.001	3	0	0	-	-	-	0.0005
PMRA 1307555	Eight US urban streams (1993-1994)		0.01	215	2	0.9	-	-	0.027	0.005
PMRA 1345964	Raw water intake, US (1999-2000)		0.003	323	2	0.6	-	-	0.05	0.0015
PMRA 1345586	Raw water from farm dugouts and recreational water bodies in southwestern Manitoba (1995)		2.0	127	0	0	-	-	-	-
PMRA 1460603	Surface water in the US (1991-2006)	Urban land use	0.002-3.4	5484	55	1.0	0.04	0.06	0.5	0.009
		Agricultural land use	0.002-3.4	10,674	879	8.2	0.34	0.59	32.2	0.037
		Mixed land use	0.002-3.4	9305	447	4.8	0.06	0.14	1.1	0.012
		Other land use	0.002-3.4	1837	33	1.8	0.19	0.03	5.8	0.012
PMRA 1311123	Urban runoff from six rain events and three receiving water bodies, Quebec (2001)		0.06	24	0	0	-	-	-	0.03
PMRA 1401896	Lake Ontario tributaries (2001)		0.1	119	0	0	-	-	-	0.05
PMRA 1401897	Lake Ontario tributaries (2000)		0.1	75	0	0	-	-	-	0.05
PMRA 1401898	Lake Erie tributaries (1998-1999)		NR	89	0	0	-	-	-	-
PMRA 1307573	Surface waters in Manitoba (1972-1994)		1.0-2.0	565	0	0	-	-	-	-
PMRA 1307580	Grand, Saugeen and Thames Rivers, Ontario (1981-1985)		<1	447	0	0	-	-	-	-
PMRA 1307575	Pond water (1985-1986)		2.5	61	0	0	-	-	-	-
	Pond water (1987)		0.2	3	0	0	-	-	-	0.1
	Spring runoff (1987)		0.2	22	3	13.6	0.94	1.04	1.09	0.21
Carbofuran Residues in Municipal Drinking Water Sources and Groundwater (not included in the ecoscenario assessment)										
PMRA 1469753	Public water systems in 16 States; surface and groundwater (1984-1999)		NR	13926	9	0.004	-	-	0.03	-

Data Source	Location		Min detection or detection limit (µg/L)	# of systems tested (or absolute number of samples)	# of systems or samples with detections	Detection frequency (%)	CONCENTRATIONS (µg/L)			
							Mean detection	95th	Absolute Max	Arithmetic Mean Including non-detects at ½ LOD
PMRA 1307565	Wells in potato growing region of Quebec	1991	0.02	35	6	17.1	0.28	0.6	0.7	0.057
		1992	0.02	46	7	15.9	0.43	1.1	1.4	0.074
		1993	0.02	34	3	8.8	0.46	0.9	0.99	0.05
PMRA 1303803	Saskatchewan (1985-2002)		0.02 - 1	54	0	0	-	-	-	0.012
PMRA 1307578	Wells near apple orchands in Quebec (1994-1996)		0.02-0.04	42 wells	0	0	-	-	-	0.013
PMRA 1403269, 1311111, 1311112	Two farm wells in Thomas Brook Watershed, NS (2004)		0.04	6	0	0	-	-	-	0.02
	Groundwater samples in PEI (2003-2004)		0.04	230	0	0	-	-	-	0.02
PMRA 1398451, 1398452, 1398453	Water distribution systems in Quebec		0.01-0.6	213 systems	1	-	-	-	0.2	-
PMRA 1311119, PMRA 1311120	Private wells, Bas Saint-Laurent (Region 1)	2001	0.02	7	0	0	-	-	-	0.01
	Private wells, Saguenay Lac-Saint-Jean (Region 2)	2000	0.03	10	0	0	-	-	-	0.015
		2001	0.02	6	0	0	-	-	-	0.01
	Private wells, Québec (Region 3)	1999	0.04	18	1	5.6	0.04	-	0.04	0.021
		2000	0.03	14	2	14.3	0.03	0.03	0.03	0.016
		2001	0.02	12	0	0	-	-	-	0.01
	Private wells, Estrie (Region 5)	1999	0.04	3	0	0	-	-	-	0.02
	Private wells, Lanaudière (Region 14)	1999	0.04	17	0	0	-	-	-	0.02
		2000	0.03	9	3	33.3	0.04	0.06	0.06	0.022
		2001	0.02	15	2	13.3	0.04	0.05	0.05	0.013
	Private wells, Centre du Québec (Region 17)	1999	0.04	1	0	0	-	-	-	0.02
		2001	0.02	9	0	0	-	-	-	0.01
PMRA 1460579	Groundwater in the US (1992-2006)	Urban land area	0.003-2.02	2660	8	0.3	0.03	0.069	0.093	0.009
		Agricultural land use	0.003-2.02	4502	54	1.2	0.132	0.167	2.16	0.017
		Mixed land use	0.003-2.02	5780	53	0.4	0.174	0.155	0.3	0.013
		Other land use	0.003-2.02	2119	17	0.8	0.058	0.160	0.173	0.009
PMRA 1311126	Envirodat database PEI groundwater		0.001	135	0	0	-	-	-	0.0005
PMRA 1345897	Wells in PEI (1996-1998)		NR	272	0	0	-	-	-	-
PMRA 1307567	PEI groundwater		0.5	12 samples	0	0	-	-	-	-
PMRA 1640595	Municipal water supplies in New Brunswick, surface water and groundwater (2003)	Spring	0.01	7	0	0	-	-	-	-
		Summer	0.4	6	0	0	-	-	-	-
		Fall	1	6	0	0	-	-	-	-

Data Source	Location	Min detection or detection limit (µg/L)	# of systems tested (or absolute number of samples)	# of systems or samples with detections	Detection frequency (%)	CONCENTRATIONS (µg/L)			
						Mean detection	95th	Absolute Max	Arithmetic Mean Including non-detects at ½ LOD
PMRA 1311123	Effluent of seven municipal water treatment plants, Quebec (2001-2002)	0.06	193	0	0	-	-	-	0.03
PMRA 1345591	Community and private water wells in the Upper Fraser Valley, Central Fraser Valley and part of the Boundary Health Units (1992-1993)	1	74	0	0	-	-	-	-
PMRA 1307575	Groundwater (1985-1986)	2.5	92	0	0	-	-	-	-
	Groundwater (1987)	0.2	15	0	0	-	-	-	0.1

3.3 Ecoscenario Exposure Estimates from Monitoring Data

The acute and chronic exposure estimates for carbofuran in Canadian surface water are presented in Table 4. The acute exposure value was estimated from monitoring data by determining the 95th percentile of the maximum concentration detected in each monitoring study/site. The chronic exposure value was estimated by determining the 95th percentile of the arithmetic means of all samples at each site (detects and non-detects) from the monitoring studies. The samples with values less than the LOD were given a value of LOD. Groundwater data and data from water distribution systems were not included in the ecoscenario assessment.

Table 4 Concentrations of Carbofuran in Surface Water Estimated from Available Monitoring Data

Acute Concentration (g/L)*	Chronic Concentration (g/L)**
4.1	0.14

* 95th percentile of the maximum detected concentrations from surface water monitoring studies
**95th percentile of the mean concentration for each study site including LOD for non-detects

4.0 Discussion and Conclusions

4.1 Discussion of Exposure Estimates for Ecoscenario

The concentrations of carbofuran in wetlands are reported as a range consisting as upper bound and lower bound concentrations rather than a discrete exposure value. The upper bound values are represented as the Level 1 EECs in wetlands, estimated by PRZM-EXAMS for the one-in-ten year exposure (or 90th percentile) (Table 2). These upper bound concentrations represent the highest concentrations of carbofuran expected in surface water in Canada for the peak, 96-hour, 21-day, 60-day, 90-day, and 1 year time periods. Upper bound concentrations were reported for wetlands 80 cm deep.

The lower end of the range was derived from the available monitoring data on carbofuran and represents the lower bound estimates of an acute and chronic concentration of carbofuran in surface water in Canada (Table 4). No time frames other than acute and chronic could be calculated using the monitoring data. No region-specific EECs are provided. The lower bound acute and chronic exposure values were estimated from monitoring data using the 95th percentiles of the maximum and arithmetic mean concentrations (including non-detects) measured in each monitoring study/site, respectively.

The concentrations of carbofuran detected in water were obtained from studies conducted in various regions across the country. Many of the samples were analyzed in the 1990's and early 2000's. The acute and chronic concentrations predicted by PRZM-EXAMS are higher than those determined by the monitoring data. This is because water monitoring, as conducted in many of the studies reviewed, involves sampling that is limited in time and space and is unlikely to detect the true maximum concentration of the analyte in question. On the other hand, the models predict the concentration expected on a daily basis which allows for the determination of a peak (acute) concentration.

Appendix XI Environment Study Summaries

PMRA 1307570 - Berryman and Giroux (1994) - Sampling stations were set up in rivers that flowed through intensive corn growing regions (Yamaska, Noire, Blanche, Saint-Zéphirin, Saint-Germain, Salvail, Chibouet, des Hurons, l Acadie, de la Tortue, à la Barbue, Saint-Régis and des Fèves Rivers). During August 1992, six sites were sampled, one time per week and six were sampled one time every two weeks. During September and October of 1992 the sampling frequency decreased to one time every two weeks and one time per month, respectively. During the remainder of the year samples were only collected once a month. During 1993 between May and August all of the sites were sampled three times per week. Only two sites were sampled during the rest of the year (des Hurons and Chibouet). The sampling frequency of these two sites was once per week in May and August and once per month during the remainder of the year. Few carbamate pesticides were included in the analyte list of this study. Carbofuran was detected in 15 out of 575 samples. Detections occurred in the Salvail, à la Barbue and des Hurons Rivers. The maximum detection was 1.5g/L. The limit of detection was 0.2 g/L.

PMRA 1640595 - Boldon and Harty (2003) - Municipal drinking water sources in New Brunswick were monitored for pesticides in the spring, summer and fall of 2003. The water sources included groundwater and surface water supplies in Fredericton, Rivière Verte, Saint-André, Grand-Sault, Drummond, Tracadie-Sheila, Charlo and St. Stephen. No pesticides were detected in any sample. The limit of detection for carbofuran was 0.01 g/L in the spring, 0.4 g/L in the fall and 1 g/L in the winter. A total of seven samples were collected in the spring, 2 samples were collected in the summer and 6 samples were collected in the fall. The detection limits for the summer and fall were high, relative to the levels detected in other studies. Using half the detection limit for the non-detects would result in an average higher than levels of carbofuran detected in other studies. Use information for carbofuran was not reported in the areas sampled.

PMRA 1307573 - Currie and Williamson (1995) - This report summarizes monitoring data for pesticides in surface waters of Manitoba, from 1972 to 1994. The data summarized are from Manitoba Environment as well as EC databases. The number of samples for carbofuran was 565 (548 from Manitoba Environment and 17 from Environment Canada). There were no detections of carbofuran. The detection limit was 2.0 g/L for the Manitoba Environment and 1.0 g/L for the EC data. The data were not used in the calculation of the exposure estimates, as the detection limits were high and half of the LOD would result in a concentration higher than most detections of carbofuran in other studies

PMRA 1307565 - Giroux (1995) - The level of contamination of groundwater by pesticides and nitrates in the potato growing region of Quebec was investigated in this study. Sampling was conducted in private wells near potato fields. The wells belonged to potato producers, or their neighbours. Most of the wells sampled are shallow, less than 10 metres. These wells are generally located less than 50 metres from potato fields. In 1991, the wells chosen for sampling had previously been heavily contaminated with aldicarb in the past. In 1992 and 1993, wells where detections of nitrates or pesticides were reported were re-sampled. Wells which had no detections of nitrates or pesticides were not resampled the following year, and sampling was conducted at other wells. Most of the wells were sampled only once or twice per year, during the

summer and the fall. However, two wells located in Saint-Ubalde and in Lavaltrie were sampled monthly from June to November, 1993. Carbofuran was detected in 16 out of 114 samples, at a maximum concentration of 1.4 g/L. Note that the report states the maximum detection was 1.8 g/L, but that the tables summarizing the data show a maximum concentration of 1.4 g/L. The latter value was used in this assessment. The limit of detection was 0.02 g/L.

PMRA 1307567 - Blundell & Harman (2000) - A Survey of the Quality of Municipal supplies of Drinking Water from Groundwater Sources in Prince Edward Island by the Sierra Club of Canada, Eastern Canada Chapter, University of Waterloo, Department of Earth Sciences. The report indicated that 12 samples from 20 wells were analyzed for pesticides. The time of year the samples were collected was not noted in the report. No detections of carbofuran were reported. The reporting limit was 0.5g/L. It can not be concluded that groundwater will not be impacted since very few samples were analyzed, the location of the sampling related to the application field and the timing of the sampling in relation to the application of carbofuran are not known. The results of this study were not used in the calculation of the exposure estimates, due to the absence of detections and the high detection limit.

PMRA 1307580 - Frank and Logan (1988) - Water samples were collected close to the outlet of the Grand, Saugeen and Thames River, Ontario, between January 1981 and December 1985. Water samples were collected during storm runoff and base flow conditions. A total of 454 unfiltered samples were collected and analyzed for 20 herbicides, 25 insecticides and 3 fungicides. Carbofuran was not detected in any sample. This study was not included in the overall average calculation as the limit of detection is not specified other than '<1 µg/L'.

PMRA 1307569 - Giroux *et al.* (1997) - As a continuation of the 1994 and 1993 sampling project to monitor pesticides in the corn growing regions of Quebec (Berryman and Giroux, 1994; PMRA 1307570) the goals of this study were to continue to examine the contamination of water bodies previously sampled for pesticides, to compare concentrations in small and large water bodies, to expand the monitoring to other high intensity corn growing regions and to verify the contamination of groundwater (triazine pesticides only). Surface water samples were collected three times per week, from mid-May to mid-August in 1994, and from early June to mid-August in 1995. A total of 210 and 155 samples were collected in 1994, and 1995, respectively. Carbofuran was detected in a total of 51 samples, in the Chibouet, des Hurons, Saint-Régis, des Anges, Yamaska Rivers. The maximum concentration was 1.3 g/L, in the des Huron River in 1995. The limit of detection was 0.02 g/L.

PMRA 1307568 - Giroux (1999) - In continuation of the sampling conducted in 1994 and 1995 (Giroux, 1997; PMRA 1307569) four rivers (Chibouet, des Hurons, Saint-Zéphirin and Saint-Régis) were sampled and analyzed for pesticide detections three times a week from the end of May to the end of August of 1996, 1997 and 1998. This study was conducted to assess the potential impact of pesticides used on corn and soya on water resources. Carbofuran was detected in des Hurons and Saint-Régis in 1996 with a maximum detection frequency of 41.5%. In 1997 carbofuran was detected in des Hurons and Saint-Régis with a maximum detected frequency of 23.1%. The number of rivers with detections of carbofuran increased in 1998 and included Chibouet, des Hurons, Saint-Régis and Yamaska with a maximum detection of 42.2%. The maximum levels of carbofuran detected were in 1996 in the des Hurons and Saint-Régis Rivers, with concentrations of 1.9 and 1.5 g/L, respectively. The limit of detection was 0.04 g/L.

PMRA 1307578 - Giroux (1998a) - Drinking water samples were collected from 42 wells located less than 50 m from apple orchards. The majority of the wells were only tested once between 1994 and 1996 whereas 14 were tested two or three times. The majority of wells were shallow, but 8 of them were deep wells. Carbofuran was not detected in the well water samples. Ambient water samples were collected approximately once a week over the summer (end of May to end of August) from three streams draining watersheds containing a number of apple orchards. A total of 111 ambient water samples were analysed. Carbofuran was detected in two of the surface water samples taken from the Déversant du Lac in 1994. The maximum concentration detected was 0.15 g/L. The detection limit was 0.02, 0.02, and 0.04 g/L, for 1994, 1995 and 1996, respectively.

PMRA 1307581 - Giroux (1998b) - This document summarizes the impact of the utilization of pesticides on water quality in the watersheds drained by the Yamaska, L Assomption, Chaudière and Boyer Rivers. A number of rivers and streams within each watershed were sampled in 1996 and 1997. Sampling occurred three times per week from the end of May to mid-July in 1996, and from the end of May until the end of July for rivers targeted for cereal crops, and until the end of August for rivers targeted to vegetable crops. Carbofuran was detected in tributaries of two of the water bodies sampled (Corbin stream, a tributary to the Yamaska River, and L Achigan River, a tributary to the L Assomption River). The limit of detection was 0.04 g/L. The maximum concentration detected was in the Corbin stream, at 8.9 g/L in 1997.

PMRA 1307571 - Giroux (2002) -In continuation of the sampling conducted in 1996, 1997 and 1998 (Giroux, 1999) four rivers (Chibouet, des Hurons, Saint-Zéphirin and Saint-Régis) were sampled and analyzed for pesticide detections three times a week from the end of May to the end of August. Data are also shown for the Yamaska River, sampled in 1999 and 2001. This study was conducted to assess the potential impact of pesticides used on corn and soya on water resources. Carbofuran was detected in 2.2 - 15.9% of the samples analyzed, with a maximum detection of 2.7g/L in the des Huron River in 1999. The limit of detection was 0.05, 0.06, and 0.07 g/L, in 1999, 2000 and 2001, respectively.

PMRA 1311119, 1311120 - Giroux (2003) - The level of contamination of groundwater by pesticides and nitrates in the potato growing region of Quebec was investigated in this study in order to provide an update on the level of contamination observed since the monitoring conducted in the early 1990s (Giroux, 1995). Sampling was conducted in 1999, 2000 and 2001, in a total of 79 private wells near potato fields in Quebec. The wells belonged to potato producers, or their neighbours. The wells provide drinking water to approximately 225 people. Most of the wells sampled are shallow, with a median depth of 5.7 metres (range in depth from 1.5 to 76 metres). These wells are generally located less than 30 metres from potato fields (range from 0 to 1 km, with two wells directly on the potato field. Wells were sampled in the fall. Generally, unless permission was refused by the owners, wells in which pesticides were detected were sampled again the following year. Wells which had no detections of nitrates or pesticides were not re-sampled the following year, and sampling was conducted at other wells. Most of the wells were sampled only once or twice per year, during the summer and the fall. Carbofuran was detected in 8 out of 121 samples, with a maximum concentration of 0.06 g/L. The limit of detection was 0.04, 0.03, and 0.02 g/L, in 1999, 2000 and 2001, respectively.

PMRA 1311123 - Giroux and Therrien (2005) - The objective of the study was to determine the presence of lawn pesticides in water and air next to treated urban areas, in order to better evaluate their impact on the natural environment. Effluent from seven municipal waste water treatment plants, as well as water in storm sewers were sampled in 2001 and 2002. Samples consisted of 24 hour composites, and were collected three times a week from mid-May to mid-July in 2001 and 2002. A maximum of 30 samples per station were collected. Water from six storm sewers and three receiving water bodies (upstream and downstream of urban areas) were sampled following a precipitation event on May 28, 2001, which corresponds to a high pesticide use period. The limit of detection for carbofuran was 0.06 g/L. Carbofuran was not detected in any of the 193 samples from effluent from the municipal waste water treatment plants, or in any of the 24 samples from storm sewers and receiving water bodies.

PMRA 1311130 (2002) - Unpublished data were supplied by Manitoba Conservation on pesticides in Manitoba from 1990 to 2001. A total of 1447 samples were collected between 1990 and 2001. Data from 1990 to 1994, inclusively, seem to have been incorporated in Currie and Williamson (1995; PMRA 1307573) and therefore were not included in the analyses. A total of 922 samples were collected between 1995 and 2001. Carbofuran was not detected in any sample. The limit of detection ranged widely, from 0.2 to 10 g/L. The samples for which the limit of detection was above 0.2 µg/L were not included in the estimation of the chronic average, as these limits of detection were high and half of the LOD would result in a concentration higher than most detections of carbofuran in other studies.

PMRA 1311131 (2004) - Unpublished water monitoring data on pesticides were supplied from Manitoba Water Stewardship from 2001 to 2003. A total of 283 carbofuran samples were collected (100, 121 and 62 samples in 2001, 2002 and 2003, respectively). Carbofuran was not detected in any sample. The limit of detection was 0.2 g/L.

PMRA 1345897 - Cantox Environmental (2003) - This report reviews pesticide use, research and monitoring activities in the Maritime Region (Nova Scotia, New Brunswick and Prince Edward Island). Monitoring data for pesticides in PEI groundwater from 1996 to 1998 were summarized. Samples were collected from 30 wells in areas of intense agriculture on six occasions and from 30 wells from across PEI on three separate occasions. Carbofuran was not detected in any of the 272 samples analyzed. The limit of detection was not reported. Thus, the results of the study could not used in the assessment.

PMRA 1307555- Hoffman *et al.* (2000) - Seventy-five pesticides (23 insecticides, 52 herbicides) and seven transformation products were monitored in eight urban streams in the United States in 1993 and 1994. Paired agricultural streams were used for six of the urban streams. Approximately four to eight samples per month were collected between May and September, and one to two samples per month were collected the rest of the year. The total number of samples collected was 215. The reporting limit was 0.01 g/L for carbofuran. Carbofuran was detected in 0.9% of samples, and the maximum concentration was 0.027 g/L.

PMRA 1460579, 1460603 - NAWQA (2006) - The National Water Quality Assessment Program (NAWQA) USGS data of residue detections from 31 integrator sites on large rivers and streams in addition to ground water sources from agricultural and urban wells. The well samples do not represent drinking water directly, and some of the wells are shallow monitoring wells. All samples analyzed in this program are filtered prior to analysis. Data were available from the years 1991 to 2006. Carbofuran was detected in 102 out of 15061 groundwater samples, and in 1414 out of 27302 surface water samples. The maximum detection in groundwater and surface water was 2.16 and 32.2 g/L, respectively. The limit of detection was 0.002 to 3.4 g/L. Surface water data were downloaded August 27, 2007 and groundwater data were downloaded August 22, 2007.

PMRA 1469753 - The National Contaminant Occurrence Database (NCOD) - This database includes Public Water Supply (PWS) contaminant occurrence data. Water quality testing is performed at many points along public drinking water supplies, including the intake and at various points in the treatment and distribution systems, as well as at the point where the drinking water can be labeled "finished." The PWS database includes information for both groundwater and surface water sources. Positive pesticide residue detection does not *necessarily* indicate a positive detect at the end of tap - but it might - especially given the great variation in water treatment systems and their efficiency. The sample data in the Six Year Review of National Drinking Water Regulations were collected between 1984 and 1999, although most of the samples were collected between 1993 and 1997. The USEPA conducted detailed contaminant occurrence analyses for 61 regulated contaminants, using data provided by a national cross-section of 16 states. Carbofuran was detected in 9 out of 13,926 samples. The limit of detection was not reported. This study was not used in the ecoscenario assessment.

PMRA 1311126 - Somers et al. (1999) - The report gives an overview of the conditions of water quality in PEI watersheds. Along with pesticides, major ions, metals, nutrients and faecal bacteria were examined, when available. The data used in this report are from the Canada-PEI Water Annex to the Federal Provincial Framework Agreement For Environmental Cooperation in Atlantic Canada, as well as from EC's Envirodat database. Some of the results of the Envirodat database were presented for pesticides. Carbofuran was not detected in any of the groundwater, freshwater or estuarine water samples collected. The limit of detection was 0.001 g/L. The report states that the sampling covers a significant period of time and can not easily be used to assess current conditions.

PMRA 1401896 - Unpublished water monitoring data as part of the Urban Pesticide Monitoring Program - 2001. A total of 119 water samples were analyzed for pesticides in eight Canadian tributaries of Lake Ontario. Carbofuran was not detected in any sample collected. The limit of detection was 0.1 g/L.

PMRA 1401897 - Urban Pesticide Monitoring Program - 2000. A total of 75 water samples were analyzed for pesticides in eight Canadian tributaries of Lake Ontario. Carbofuran was not detected in any sample collected. The limit of detection was 0.1 g/L.

PMRA 1401898 - Unpublished water monitoring data on pesticide concentrations in eight Canadian tributaries of Lake Erie. A total of 89 samples of N-methyl carbamates were collected between 1998 and 1999. The limit of detection was not reported. This study was not used in the calculation of the water concentration estimates.

PMRA 1307560 - This study investigated the potential for surface water contamination in the Don and Humber River watersheds, resulting from the use of lawn care pesticides. Samples were analyzed for up to 152 pesticide active ingredients and eight transformation products. These included phenoxy acid herbicides, triazine herbicides, organophosphorus insecticides, and other pesticides associated with lawn care use. Sampling was conducted from 1998 to 2002. A total of 262 samples were collected: 123 wet events (shortly after the start of precipitation or during the peak flow period) and and 139 dry events. Sampling frequency differed from year to year, and ranged from February to December. The method detection limits were reported to be 0.05 g/L for most of the organophosphorus insecticides and for the triazine herbicides, 0.1g/L for organonitrogen, organochlorine and carbamate pesticides, 1.0 g/L for imidacloprid and 0.02g/L for diazinon and atrazine. Carbofuran was detected in 22 samples, but only two of these were quantifiable (above the method detection limit of 0.1 g/L). The maximum detection was 3 g/L. In the calculations, a value equal to the method detection limit was given to samples which were detected but not quantifiable. Samples below the detection limit were assigned half the method detection limit in the calculation of the overall average.

PMRA 1307575 - Waite et al. (1992) - The occurrence and concentration of pesticides in groundwater, surface (pond) water and runoff from spring snowmelt was investigated in a small agricultural watershed in south-central Saskatchewan between 1985 and 1987. Analyses of the herbicides 2,4-D, dicamba, bromoxynil, diclofop-methyl and triallate were conducted. Water samples were also tested for the insecticides carbofuran, carbaryl, chlorpyrifos, dimethoate and detalmethrin because of insecticide treatment in the study area to control grasshopper infestations in 1985 and 1986. A total of 105 groundwater and 64 pond water samples were collected. Groundwater samples at 3 to 4 metres from the ground surface were collected weekly in 1985 and 1986, and on four occasions in 1987. Surface water samples were collected weekly in 1985 and 1986 and twice in 1987 from one site in two reservoirs. Spring runoff samples were collected on nine sequential days during active flow in 1985 for herbicide analysis and in 1987 for herbicide and insecticide analysis. Thirty-seven samples were collected from six sites in 1985. In 1987, twenty-two samples were collected from seven sites. Detection levels for carbofuran were 2.5 g/L in 1985 and 1986, and were lowered to 0.2 g/L in 1987. No insecticides were detected in any groundwater or surface water samples. Carbofuran was measured in three spring runoff samples from one site in 1987. Levels detected were 0.86 to 1.09 g/L. Runoff samples were not analysed for insecticides in 1985. Data from groundwater and pond water samples collected in 1985 and 1986 were not used, as the detection level was high. It was assumed that the detections were 0.86, 0.86 and 1.09 g/L in the calculation of the chronic exposure estimate for spring runoff in 1987.

PMRA 1345964 - Blomquist *et al.* (2001) - A monitoring program of pesticides in drinking water was undertaken by the U.S. Geological Survey and the U.S. Environmental Protection Agency. Sampling was conducted in twelve water supply reservoirs in the years 1999 and 2000 in California, Indiana, Ohio, Oklahoma, Louisiana, Missouri, South Carolina, South Dakota, New York, North Carolina, Pennsylvania and Texas. Samples were collected four times per year, as

well as weekly and bi-weekly intervals following the high use periods. Water samples were collected from the raw-water intake, the finished drinking water tap prior to entering the distribution system, as well as at the reservoir outflow, in some locations. A total of 178 pesticides and transformation products were analysed, using three analytical methods. A total of 323 raw water and 228 finished water samples were analyzed for carbofuran. The statistically derived method reporting level was 0.003 g/L for carbofuran. Only results of raw water are reported here. Carbofuran was detected in two raw water samples (0.6% detection). The maximum detection was 0.05 g/L.

PMRA 1398451, 1398452, 1398453 - Giroux *et al.* (2006) - The objective of this pesticide monitoring study was to determine the impact of pesticides used on corn and soy crops in four rivers that have been monitored since 1992 (Chibouet River in Yamaska River watershed, des Hurons River in Richelieu River watershed, Saint-Régis River, flowing directly in Saint-Lawrence River, and Saint-Zéphirin River, in Nicolet River watershed). The rivers were sampled for pesticides three times per week from mid-May to mid August of 2002, 2003 and 2004. In addition, pesticides were measured four times a year in 213 drinking water distribution systems from 2001 to 2004. The limit of detection for carbofuran in surface water was 0.06 g/L. Carbofuran was detected in 11 samples collected in the des Hurons River and in one sample collected in the Saint-Régis River. The maximum detected concentration was 0.67 g/L. Carbofuran was analyzed in samples collected from 213 water distribution systems. Carbofuran was detected in the La Sarre system (0.2 g/L) in 2003. The limit of detection was not specified, and thus a chronic average can not be calculated. The limit of detection was reported as ranging from 0.01 to 0.6 g/L in water distribution systems. The total number of samples collected was not reported.

PMRA 1345586 - Jones *et al.* (1998) - A water quality survey of rural surface water supplies in southwestern Manitoba was conducted in 1995. A total of 113 farm dugouts and 14 recreational water bodies were sampled for pesticides, nutrients, biological components, trace metals, and general physical and chemical characteristics. Pesticides were only measured in raw water. Carbofuran was not detected. The limit of detection was 2.0 g/L. This study will not be used in the estimation of the chronic average, as the detection limit is high and half of the LOD would result in a concentration higher than most detections of carbofuran in other studies.

PMRA 1303803 (2002) - Unpublished water monitoring data from Saskatchewan (1979 - 2001) supplied by the Environmental Protection Branch, Saskatchewan Environment and Resource Management. Samples are from private wells, dugouts, distribution systems, etc. Carbofuran samples were collected between 1985 and 2002. The detection limits ranged from 0.02 to 1 g/L. The samples with detection limits greater than 0.05 g/L were not included in this assessment, as the detection limit was high compared that of the other studies. A total of 105 samples were reported, 54 of which had limits of detection of 0.05g/L or less. No detections were indicated in any sample.

PMRA 1345591 – (2001) Unpublished groundwater monitoring data of pesticides in the Fraser Valley, BC. A total of 74 samples were analyzed for carbofuran from 1992 to 1993 in community and private wells of the Fraser Valley. No detection of carbofuran were reported. The detection limit was 1 g/L. As this is higher than some other studies and there were no detections, results of this study were not included in the calculation of the chronic average, as it may falsely increase the average significantly.

PMRA 1403269 (2006) (also encompasses 1311110, 1311111 and 1311112) - As part of the Pesticide Science Fund, monitoring for carbofuran in water occurred in the Quebec Region and in the Atlantic Region. In the Quebec Region, 5 stations (mouth of the Yamaska, Saint-François and Nicolet Rivers, in Lac Saint-Pierre (Port Saint-François) and in the Saint-Lawrence River near Québec) were sampled. In the three tributaries, samples were collected weekly from the end of May and the end of August in the three tributaries from 2003 to 2005. Bimonthly samples were collected at the mouth of the Saint-Lawrence from the beginning of May until the end of August 2003, monthly between September 2003 and February 2004 and then weekly from the beginning of June 2004 and the end of August 2004. In Port Saint-François, sampling occurred weekly from the end of May to the beginning of September in 2004 and 2005. The limit of detection was 0.06 g/L in the Rivers and 0.003g/L in the Saint-Lawrence. Carbofuran was not detected in any sample from the Quebec Region. In the Atlantic Region, surface water and groundwater sampling occurred in Nova Scotia, New Brunswick and Prince Edward Island. The limit of detection was 0.04 g/L. A total of 41 samples were analyzed for carbofuran in New Brunswick surface water from 2003 to 2005. Carbofuran was not detected. In Nova Scotia, sampling occurred between June and October in 2004 and 2005. Carbofuran was not detected in any of the 19 samples analyzed. In Prince Edward Island, a total of 82 surface water samples were collected between July and October from 2003 to 2005. Carbofuran was detected in 2 samples (0.03 and 0.59 g/L in the Mill and Founds River, respectively). For groundwater, samples from Prince Edward Island were collected in late fall and early winter, to coincide with fall groundwater recharge period. A total of 355 samples were collected (108, 122 and 125 samples in 2003, 2004, 2005, respectively). Results from the 2005 sampling were not available. In Nova Scotia, six groundwater samples were collected in two farm wells located in the lower portion of the Thomas Brook watershed in 2004. Carbofuran was not detected.

Appendix XII Carbofuran uses for which information on value is sought: site-pest combinations of Restricted Class products that are supported by the technical registrant and for which risk concerns have been identified.

Site(s)	Pest(s)	Support[1]	Concerns from Risk Assessments[2]	Identification of Risk Assessment Concerns
Use-site Category 7 Industrial oilseed and fiber crops Use-site Category 13 Terrestrial feed crops Use-site Category 14 Terrestrial food crops				
Canola (rapeseed) Mustard	flea beetle, red turnip beetle	Y	Y	*See Section 7.0*
Sunflower	sunflower beetle	Y	Y	*See Section 7.0*
Use-site Category 13 Terrestrial feed crops Use-site Category 14 Terrestrial food crops				
Corn (Field, Silage) Western Canada only	European corn borer, Western and Northern corn rootworm adults	Y	Y	*See Section 7.0*
Sugar beet Western Canada only	sugar beet root maggot	Y,M	Y	*See Section 7.0*
Use-site Category 14 Terrestrial food crops				
Corn (Sweet)	European corn borer, Western and Northern corn rootworm adults	Y	Y	*See Section 7.0*
Pepper (green) Ontario only	European corn borer	Y	Y	*See Section 7.0*
Potato	Colorado potato beetle, potato flea beetle, potato leafhopper, tarnished plant bug	Y	Y	*See Section 7.0*
Raspberry (field) British Columbia only	bud or root weevil	Y	Y	*See Section 7.0*
Strawberry British Columbia only	root weevil, spittlebug	Y	Y	*See Section 7.0*

Site(s)	Pest(s)	Support[1]	Concerns from Risk Assessments[2]	Identification of Risk Assessment Concerns
Strawberry Eastern Canada only	strawberry weevil (blossom clipper), tarnished plant bug	Y	Y	*See Section 7.0*
TURNIP, RUTABAGA (EMERGENCY USE April 1, 2008 to August 31, 2008) British Columbia only (EMERGENCY USE May 8, 2008 to August 31, 2008) Nova Scotia only	cabbage root maggot	Y	Y	*See Section 7.0*

[1] Y = use is supported by the registrant; and M = use was registered as a User Requested Minor Use Label Expansion (URMULE).
[2] Y = there are risk concerns for this use.

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A. Additional Information Considered

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